# SNAKE PLAIN RECHARGE PROJECT
## Idaho

# SPECIAL REPORT

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UNITED STATES
DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGION 1

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BOISE, IDAHO

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGIONAL OFFICE, REGION 1
BOX 937, BOISE, IDAHO

IN REPLY
REFER TO:

To: Regional Director, Boise, Idaho

From: Regional Project Development Engineer, Boise, Idaho

Subject: Special Report -- Snake Plain Recharge Project, Idaho

This report outlines our findings based on a reconnaissance-grade investigation of the Snake Plain Recharge Project, Idaho. The investigation leading to the report was conducted as a part of the approved program for the Bureau of Reclamation General Investigations, fiscal years 1960, 1961, and 1962.

The Snake River Plain east of Bliss, Idaho, has experienced a large, stable, and highly productive irrigation development in the past, and there are future land- and water-resource potentials of great scope existing within the area. Recent Bureau of Reclamation-Corps of Engineers studies in the Upper Snake River Basin indicate that there are about 580,000 acres of new, potentially irrigable land, and 860,000 acres of land requiring a supplemental water supply in this area.

The realization of any substantial new irrigation development in the area, however, is dependent upon the development of a source of water to complement the present surface-water supply from Snake River at and above Milner Dam, which is completely used in dry years. This need can, in part, be satisfied by further development of the Snake Plain aquifer, a vast ground-water resource underlying that part of the plain broadly defined by mountains on the north, south, and east, and the Snake River from Twin Falls to Bliss as the western limit.

The aquifer is presently recharged each year by percolation from irrigation diversions on the plain, seepage from streams entering or crossing the plain, underflow from tributary basins, and precipitation in the form of rain and snow. The average annual recharge from these sources is estimated to be 6,600,000 acre-feet.

Discharge from the aquifer is into the Snake River and occurs mainly in two areas; in the reach between the Blackfoot and Neeley gaging stations, and in the reach between Twin Falls and Bliss. In the first reach, the annual discharge is estimated to be about 2,600 cubic feet
R per second. Most of the inflow in this reach is stored in American

Falls Reservoir. Discharge in the second reach averages about 7,500 cubic feet per second.

Companion with this ground-water resource is a surface-water supply that is in part unused. At Milner Dam, the last point of gravity diversion in the Upper Snake, the river is fully appropriated over a long period of dry years. However, in years of normal or above-normal runoff, there is water that spills past Milner Dam unused. Operation studies show that during the period 1928-1957 a total of about 16,600,000 acre-feet would spill past the dam in excess of present irrigation and power requirements and thus be available for recharge purposes. This surplus flow, however, does not occur regularly, and varies in amount in the years that it does occur. Over the period of study, the minimum amount of spill was 29,000 acre-feet in 1930, while the maximum was 1,879,000 acre-feet in 1951. No spill occurred during the years 1931-1938 and 1940-1942.

Artificial recharge, as outlined in this report, would consist of diverting surplus surface flows of wet years to infiltration areas where this water would enter the porous materials of the aquifer. Thus, both the transient storage provided by the aquifer and the surplus surface water that is now unused would be beneficially joined.

If the concept of artificial recharge is considered in the light of present and future water-resource developments in the Upper Snake River Basin above Bliss, it would have the effect of:

(a) Putting underground, surplus flows of Henrys Fork and Snake River that would otherwise spill past Milner unused;

(b) Increasing the flow from the aquifer into Snake River at various places between Idaho Falls and Bliss;

(c) Making available water for a variety of purposes that might not otherwise be usable in this reach of the river;

(d) Moderating a declining water-table level in some areas and forestalling this trend in other areas and encouraging new irrigation development involving ground-water pumping as a result; and

(e) Providing flood control by diversion of peak flows of Henrys Fork and Snake River.

The Snake Plain lava offers an unusually good opportunity for artificial recharge. In many places the irregular, broken surface of the lava takes water readily, and large fractures and other openings permit rapid percolation into the aquifer. Openings in the basalts and interflow zones underlying the plain have a large volume or water-holding capacity. It is estimated that a water-level rise of 10 feet in the aquifer would represent an increase in water volume underground of approximately 8,000,000 acre-feet. Because of high transmissibility coefficients, the pressure effects of recharge would spread rapidly, and large amounts of water could be recharged at one place without building a ground-water mound to excessive height.

In the determination of suitable sites for artificial recharge on the plain, several restrictive factors were taken into consideration. The selection of an area for the purposes of artificial recharge is largely dependent upon: the availability of water, a favorable topographic situation that would permit diversion of surplus flows by gravity to infiltration areas, a means of water movement from source to site that would be practical from an engineering and economic viewpoint, and a sufficiently large infiltration area with materials of adequate absorptive capacity.

From examination of the contours of the water table and flow net of the Snake Plain aquifer, it appears that artificial recharge would cover the widest area and offer the greatest benefit to present and future water use, both underground and surface, if introduced as near the head or beginning of the aquifer as possible. Recharge could then raise water levels throughout more of the aquifer.

The most suitable and effective recharge sites on the plain would be the St. Anthony, Idaho Falls, and Idaho Falls-Blackfoot Gravel Pit Recharge areas. Other recharge possibilities investigated to a lesser degree in this study are the Milner-Gooding Recharge area and the Big and Little Wood River Recharge areas, all in the western part of the project area.

Storage of surplus streamflows for the multiple purposes of irrigation, power, and flood control is traditionally thought of in terms of retaining the water in an impoundment above ground. The Snake Plain Recharge Project has the same beneficial purposes as objectives, but is unique in that the surplus water would be passed underground into the interstices, pore spaces, and caverns of the extensive lava and sedimentary rocks underlying the Great Plain of the Snake River. There it would augment an existing transient ground-water resource and could be withdrawn by pumping or would reappear downgradient in Snake River to be usable when otherwise it might not have been.

Three favorable areas for recharge of the Snake Plain aquifer are located in the eastern part of the Snake River Plain. These three areas--the St. Anthony Recharge area, the Idaho Falls Recharge area, and the Idaho Falls-Blackfoot Gravel Pit Recharge area--were selected for detailed study and constitute the development plan for this reconnaissance appraisal.

St. Anthony Recharge Area is located west of Egin Bench and Menan Buttes. The surface of basalt in this area is greatly fractured, and some of the fractures formed in pressure ridges are quite large. There are numerous closed depressions and other areas that could be closed with a small amount of construction. However, much of the basalt is covered by a blanket of windblown sand and silt that partially clogs the openings in the basalt and would reduce infiltration capacity. Nevertheless, it is believed that this area, either by water spreading or a combination of injection wells and water spreading, is well adapted for use as a recharge area. The St. Anthony Recharge area requires a headworks structure on Henrys Fork just upstream from the town of St. Anthony, a canal from the diversion structure to the recharge area, four ponding areas, and enlargement of the existing Egin Lakes.

Idaho Falls Recharge Area lies in the lavas west of the town of Idaho Falls. The area would receive surplus water through a canal heading a few miles southeast of Roberts, Idaho. Facilities in the development plan include a headworks structure, enlargement of approximately 11 miles of the Great Western Canal, and the construction of about 7 miles of new canal. Natural depressions would be utilized as ponding areas. The lava in the disposal area is much more broken up and contains less soil-and-silt cover than the St. Anthony area.

Idaho Falls-Blackfoot Gravel Pit Recharge Area along the Snake River between Idaho Falls and Blackfoot would utilize surplus flows by diversion of water to a series of gravel borrow areas, some of which have bottom grades lower than the river. A total of about 6 miles of canal at separate locations would comprise the facilities required for diversion to the gravel pits.

It is concluded from this study that the diversion of surplus flows from Henrys Fork and Snake River, and the delivery of these flows to the St. Anthony, Idaho Falls, and Idaho Falls-Blackfoot Gravel Pit Recharge areas for the purpose of artifically contributing to the recharge of the Snake Plain aquifer would be a beneficial application of water now unused in the area. Further, plans for doing this would have economic justification and engineering feasibility. Project benefits would apply in some degree to more than 100,000 people and many water-use functions, and the identification of the individual beneficiaries and of the amount of benefits accruing to each would be very difficult, if not impossible. Hence, an acceptable means of obtaining repayment of reimbursable costs is not apparent at this time.

On the basis of this investigation, I recommend that:

(1) This report be furnished to the present water users in the Snake Plain and to other individuals and groups interested in development of the land and water resource of the State.

(2) A thorough canvass be made by public hearings, or direct contact with the people and water user interests to determine the extent of interest in, and support for the project.

(3) Feasibility studies be undertaken when there is strong evidence of support for and interest in the project, and when a solution to the question of repayment of reimbursable project costs is apparent.

E. L. White

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGION 1

# S N A K E   P L A I N   R E C H A R G E   P R O J E C T

# I D A H O

SPECIAL REPORT

Boise, Idaho

# STATISTICAL SUMMARY

Snake Plain Recharge Project
Idaho

## LOCATION

The Snake Plain Recharge Project involves an area within the Upper Snake River Basin lying mainly on the north side of Snake River, extending upstream some 200 miles north and east from Bliss to Ashton, in southeastern Idaho. Project artificial recharge areas would be located as follows: (1) the sand and lava area west of St. Anthony, (2) the lavas west of Idaho Falls, and (3) existing gravel pits adjacent to Snake River from Idaho Falls to Blackfoot.

## AUTHORIZATION

Investigations leading to this report are authorized by Federal Reclamation Law (Act of June 17, 1902, 32 Stat. 388, and Acts amendatory thereof and supplementary thereto).

## PLAN

The Snake Plain Recharge Project would serve the multipurpose functions of irrigation, power, flood control, recreation, and fish and wildlife. Water for municipal and industrial purposes and pollution abatement control would be made available, but costs and benefits associated with the future long-term needs for these functions have not been evaluated.

The development plan provides for diversion headworks and canals to divert and transport flows of Henrys Fork and Snake River that are in excess of downstream priorities, to infiltration areas for purposes of artificially contributing to the ground-water resource of the Snake River Plain.

Recharge water would be stored in the porous materials underlying the Plain, and would move slowly downgrade to re-enter Snake River in the form of springs at a somewhat uniform rate above Bliss, Idaho. This artificial recharge would tend to stabilize the regional water table to the benefit of both present and future ground-water pumping for purposes of irrigation, municipal, industrial, and other needs, and would serve as a measure of flood control by diverting flood flows from Henrys Fork and Snake River. The increased ground-water inflows to Snake River would stabilize, to some extent, the river flows and benefit surface-water irrigation, power production, and other functions.

## Statistical Summary - Snake Plain Recharge Project

### COSTS

Prices as of April 1961

| Area | Construction Cost - Total | Annual O&M Costs |
| --- | --- | --- |
| St. Anthony Recharge Area ........ | $ 4,460,000 1/ | $ 7,500 3/ |
| Idaho Falls Recharge Area ........ | 8,380,000 2/ | 12,500 3/ |
| Idaho Falls-Blackfoot Area........ | 130,000 | 1,000 |
| Total ...................... | $13,150,000 | $21,000 |

1/ Includes $430,000 for mitigation and preservation of existing fishery.
2/ Includes $625,000 for mitigation and preservation of existing fishery.
3/ Includes $500 for fish and wildlife facilities.

### COST ALLOCATION

COSTS

| Item | Irrigation (dollars) | Power (dollar) | Flood Control (dollar) | Fish & Wildlife (dollar) | Total (dollars) |
| --- | --- | --- | --- | --- | --- |
| Total Allocated and Assigned Costs | | | | | |
| (1) Construction costs | 4,647,000 | 6,188,000 | 1,260,000 | 1,055,000 | 13,150,000 |
| (2) Interest during construction | 117,000 | 153,000 | 33,000 | 26,000 | 329,000 |
| (3) O&M | 8,000 | 10,000 | 2,000 | 1,000 | 21,000 |
| Total Annual Allocated Costs | | | | | |
| (1) Construction costs | 126,900 | 169,000 | 34,400 | | 330,300 |
| (2) Interest | 3,200 | 4,200 | 900 | | 8,300 |
| (3) O&M | 8,000 | 10,000 | 2,000 | | 20,000 |
| (4) Replacements | -- | -- | -- | | -- |
| TOTAL | 138,100 | 183,200 | 37,300 | | 358,600 |

Statistical Summary - Snake Plain Recharge Project

## REPAYMENT

In considering repayment aspects of the Snake Plain Recharge Project, many unusual and unconventional problems arise. Possible solutions to these complex problems are discussed in this report, but an absolute solution to project repayment is beyond the scope of this investigation.

## BENEFIT-COST RATIO

| Item | 100-Year Period (dollars) |
|---|---|
| Benefits (annual) | |
| Irrigation | 270,000 |
| Power | 430,000 |
| Flood control | 73,000 |
| Total | 773,000 |
| Net Federal investment | 13,359,000 |
| Annual equivalent Federal investment | 365,000 |
| Annual operation and maintenance cost | 21,000 |
| Annual total equivalent cost | 386,000 |
| Ratio | 2.00 to 1 |

## LANDS AND IRRIGATION

Existing and New Potential Irrigation Development
Snake River Basin above Bliss, Idaho

| Item | Area Benefited By ground-water Recharge (acres) | Other (acres) | Total Basin Above Bliss (acres) |
|---|---|---|---|
| Existing Irrigation | | | |
| Surface water | 1,430,000 | 320,000 | 1,750,000 1/ |
| Ground water | 240,000 | 375,000 2/ | 615,000 |
| Subtotal | 1,670,000 | 695,000 | 2,365,000 |
| New Lands 4/ | 250,000 | 330,000 | 580,000 3/ |
| Subtotal | 250,000 | 330,000 | 580,000 |
| TOTAL | 1,920,000 | 1,025,000 | 2,945,000 |

1/ 860,000 acres of this total were identified in the Upper Snake River Basin Report as requiring supplemental water.

(Footnotes continued)

2/ 180,000 acres of this total would benefit in undeterminable degrees, but not to the extent that benefits can be claimed.
3/ Represents potential new land irrigation developments as outlined in the Upper Snake River Basin Report.
4/ Both surface and ground water.

POWER

| Item | 1/ | 2/ |
|---|---|---|
| Availability of flows for diversion | 46 days | 33 days |
| Average rate of diversion | 2,860 c.f.s. | 2,240 c.f.s. |
| Increased inflows: | | |
| American Falls | 190 c.f.s. | 100 c.f.s. |
| Below Milner | 310 c.f.s. | 190 c.f.s. |
| Usability of increased flows | 80 percent | 95 percent |
| Energy production due to increased flows | 265,000,000 kw.-hr. | 326,000,000 kw.-hr. |
| Energy reduction due to decreased flows | 78,000,000 kw.-hr. | 260,000,000 kw.-hr. |
| Net average annual increase | 187,000,000 kw.-hr. | 66,000,000 kw.hr. |
| At-site value per kw.-hr. | 3.4 mills | 3.4 mills |

1/ With Teton Basin and Burns Creek Projects added to present system.
2/ Conditions with future development (as outlined in the 1961 Upper Snake River Basin Report).

FLOOD CONTROL

The diversion of floodflows from Henrys Fork and Snake River to infiltration areas on the plain would serve as a measure of flood control. The Corps of Engineers has evaluated the benefits associated with flood control for the project, and estimates that the benefit derived from flood control on the Henrys Fork and Snake River would be $34,000 annually. The Corps also advises that recharge diversions would receive downstream benefits on Lower Columbia (as described in the Upper Snake River Basin studies), amounting to $39,000 annually.

HYDROLOGY

The water available for diversion for the Snake Plain Recharge Project is only that water which is surplus at Milner Dam and is in excess of power requirements in this general reach of Snake River.

Water divertible to the three recharge sites has been considered under conditions of present development, the addition of Burns Creek and the Teton Basin Project, and future conditions as outlined in the 1961 Upper Snake River Basin Report. The average annual amounts of water available to each of the three areas during the period of study, 1928 to 1957, are shown in the following tabulation.

| Recharge Area | Average Annual Amount of Water Available for Recharge | | |
|---|---|---|---|
| | Present Conditions | Burns Creek & Teton Basin Proj. | Future Conditions |
| | (acre-feet) | (acre-feet) | (acre-feet) |
| St. Anthony | 100,000 | 83,000 | 58,000 |
| Idaho Falls | 200,000 | 165,000 | 80,000 |
| Idaho Falls-Blackfoot Gravel Pit | 15,000 | 13,000 | 10,000 |
| TOTAL | 315,000 | 261,000 | 148,000 |

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Statistical Summary - Snake Plain Recharge Project

PROJECT FEATURES

| Items or Features | RECHARGE AREA | | |
|---|---|---|---|
| | St. Anthony | Idaho Falls | Idaho Falls-Black-foot Gravel Pits |
| Diversion Dams | Existing | Existing | 1/ |
| Headworks | | | |
| Type | Concrete | Concrete | - |
| Size | 2,000 c.f.s. | 2,500 c.f.s. | - |
| Gates | Radial | Radial | - |
| Other | Fish screens (rotating) | Fish screens (rotating) | |
| Recharge Canals | | | |
| Name | St. Anthony Canal | Great Western Canal Enlargement | 1/ |
| Capacity | 2,000 c.f.s. | 2,500 c.f.s. 2/ | Range, 2 to 25 cfs |
| Length | 14.8 miles | 11 miles | 5.8 miles total |
| Name | -- | Idaho Falls Recharge Canal | -- |
| Capacity | | 2,500 c.f.s. | |
| Length | | 7 miles | |
| Recharge Ponds | | | |
| Number | 5 | 5 | 13 pits |
| Capacity range | 1,350 to 30,395 acre-feet | 420 to 6,545 acre-feet | 5 to 485 ac.-ft. |
| Total capacity | 43,500 acre-ft. | 9,810 ac.-ft. | 2,900 acre-feet |
| Surface area range | 294 to 6,078 acres | 71 to 590 acres | 1.3 to 53 acres |
| Total surface area | 8,000 acres | 910 acres | 230 24 acres |
| Dikes | | | |
| Number | 4 | 4 | - |
| Length range | 430 to 8,400 ft. | 100 to 700 ft | - |
| Height gage | 5 to 16 feet | 13 to 18 ft. | - |

1/ Diversions mainly from existing canals.

2/ Enlarged from 700 c.f.s. to 2,500 c.f.s.

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# INTRODUCTION AND GENERAL DESCRIPTION

The Snake Plain Recharge Project occupies an area principally on the north side of Snake River, from the upper topographic limits of the plain downstream to the Thousand Springs area near Bliss. Location of the general features of the project are shown on General Map, Drawing No. 932-125-20.

That part of the Snake River Plain lying east of Bliss and the Hagerman Valley to approximately Ashton and the Big Bend Ridge is largely underlain by volcanic materials that contain and convey tremendous quantities of ground water. This vast underground sequence of porous materials constitutes an aquifer in which water moves generally paralleling Snake River from the higher elevations in the northeast to the lower elevations in the southwest.

The storage capacity of the aquifer is very large. According to the U. S. Geological Survey, Ground Water Branch, the coefficient of storage probably is on the order of 10 percent, and the total porosity may be 15 to 20 percent. Assuming a coefficient of storage of 10 percent, each foot of saturated thickness of the entire 12,000 to 13,000 square miles of the aquifer would yield about 800,000 acre-feet of water. The ability of the aquifer to transmit water is great. The coefficient of transmissibility generally ranges from 1 to 60 million gallons per day per foot, and probably averages 10 million gallons per day per foot.

Discharge from the aquifer is into Snake River and is chiefly into two areas; in the reach between the mouth of the Blackfoot River and American Falls, and in the reach between Twin Falls and Bliss. According to U. S. Geological Survey studies, the average discharge from the aquifer in the first reach is about 2,600 cubic feet per second, of which about 500 cubic feet per second is recharged within the section, making the net loss from the aquifer about 2,100 cubic feet per second.

Discharge in the second area is chiefly between Twin Falls and Bliss, although there are a few small springs between Milner Dam and Twin Falls. Discharge from the aquifer on the north side of the river averages about 6,500 cubic feet per second. Ground-water inflow in this same reach from the south side of the river averages about 1,000 cubic feet per second, for a total ground-water inflow in the reach of about 7,500 cubic feet per second.

At the present time, this large aquifer is being recharged by precipitation, seepage from streams entering or crossing the plain, underflow from tributary basin, and percolation from irrigation diversions on the plain.

Henrys Fork, which enters Snake River from the north about 20 miles below Heise, is the largest tributary in the upper basin and drains the

western slopes of the Teton Range and the southern slopes of the Centennial Mountains and intervening areas. A portion of this runoff is lost through underground flow, thus also contributing to the recharge of the Snake Plain aquifer.

Tributaries west of Henrys Fork flow generally southward from the mountains that form the northern boundary of the basin. Upon reaching the plain, the runoff of these streams sinks into the highly pervious lava formations, and reappears in the springs on the north side of Snake River between Milner and King Hill. Camas, Medicine Lodge, Birch, and Fish Creeks, and Big and Little Lost Rivers are streams without a surface connection with Snake River that contribute to ground water in this way.

The Big Wood River is the westernmost tributary entering the plain from the north. This stream, and Little Wood River, lose portions of their flows into the lava formation on the plain before becoming the Malad River which enters the Snake between Hagerman and Bliss.

Tributaries entering Snake River from the south, below Heise, drain the less-rugged mountains that separate the Snake River and Great Salt Lake drainage basins. These tributaries include Willow Creek, Blackfoot River, Rock Creek, Portneuf River, Bannock Creek, Raft River, Goose Creek, Rock Creek (Twin Falls County), Deep Creek, and Salmon Falls Creek. Part of the surface runoff of these streams disappears underground near points of confluence with Snake River, most of it reappearing as spring flow and seepage along the south bank of the river. Portions of the Snake River itself, below the point where it begins to merge with the Snake Plain near Heise, is a losing stream contributing to ground water.

## LOCATION AND ACCESSIBILITY

The Snake River Basin upstream from Bliss consists of the broad, central Snake River Plain and the flanking mountain ranges. This plain, having an area of about 13,000 square miles, forms an arc averaging nearly 60 miles in width extending from Bliss northeastward approximately to Ashton, a distance of about 200 miles.

Snake Plain Recharge Project area, in general, is well served by conventional public transportation systems and a network of roads and highways. There are individual wasteland areas of large extent, however, where access is limited, but all the areas with an artificial recharge potential have fairly easy access.

## GEOLOGY AND PHYSIOGRAPHY

The surface of the Snake River Plain slopes southwestward from an altitude of more than 6000 feet north of Ashton, to about 3200 feet

near Bliss. The plain is underlain by a thick sequence of basaltic lava flows and sedimentary interbeds. The land surface appears monotonously flat from a distant view, but closer observation reveals a variety of land forms and a diversity of geologic features. Broad swells and domes mark some centers of volcanism; craters and cinders, at places aligned along great rift zones, mark others. Some of the earlier lava flows are covered with a mantle of windblown sand and silt, and in some depressions, sedimentary deposits accumulated in playas. The more recent flows are virtually bare, and ropy pahoehoe lava forms flat table and ramplike surfaces extending for hundreds of yards. At other places, the rough, blocky lava forms an exceedingly jumbled and jagged mass. Large lava caves and tubes are found in a few places, and pressure ridges and collapsed lava tubes are common features. One striking feature of the surface of some lava flows is the great number of shallow depressions commonly 5 to 10 feet in diameter that dot the surface in some areas, giving it the apparent texture from a distance of a synthetic sponge. The pressure ridges, collapsed tubes, and depressions are all greatly fractured, especially around their peripheries, and many of the fractures gape widely.

On the northwestern and southeastern flanks of the Snake River Plain are a series of subparallel mountain ranges and intervening valleys trending northwestward nearly at right angles to the plain. The mountain ranges on the northwest flank of the plain rise to altitudes of 11,000 to 12,000 feet; those on the southeast to altitudes of 7,000 to 10,000 feet. The rocks in the mountains are chiefly older, consolidated rocks including granite, quartzite, limestone, shale, sandstone, and silicic and basaltic lava rocks. In general, these have been folded and faulted into a series of northwestward-trending ranges with intervening structural valleys. The surficial expression of these structures terminates abruptly at the margin of the Snake River Plain which crosses them at approximately a right angle. The older rocks were faulted and warped downward to form a basin in which the basalt flows and associated sedimentary beds of the Snake River Plain accumulated. The thickness of the fill in this broad basin is not known. No wells more than a mile or two from the margin of the plain have penetrated deeply enough to reach the underlying bedrock.

The structural valleys between the mountain ranges flanking the plain are broad, alluvial-filled basins merging with the Snake River Plain at its margin. Many of these basins are as broad at their heads as at the mouth; obviously, the streams did not cut the valleys. The fill in these valleys consists of alluvial fan deposits, stream alluvium, and lakebeds.

## SETTLEMENT AND POPULATION

The location and growth of population on the Snake River Plain coincides with the location and rate of development of irrigated land.

All communities, with a population of at least 4,000, within this part of the Snake River Basin, are located on the banks of, or very near, Snake River or one of its tributaries.

In 1960, the population of Snake River Basin above Bliss was estimated to be 280,000. Of this number, about 273,000 people lived in Idaho and 7,000 lived in Wyoming, Utah, and Nevada. About 48 percent of the total population is urban, and 52 percent is rural. Cities with populations exceeding 2,500 are classified as urban.

The population of some of the larger cities in the area, for the census years 1940, 1950, and 1960, with percentages of increase, is shown on table 1. Urban population gain as related to increase in irrigated acreages is demonstrated by the population changes of Blackfoot and Burley. Since 1950, these two communities have increased their marketing and service areas to include large acreages of newly irrigated lands served by ground water. Their rate of growth is exceeded only by Idaho Falls, which also serves a substantial new land ground-water acreage plus the Atomic Energy Commission's National Reactor Testing Center about 50 miles to the west.

The population of counties within the area for census years 1940, 1950, and 1960 is shown on table 2. While the overall population trend within the Snake River Basin has been up, the trend for several counties is down. The effect of newly irrigated lands on county population is clearly presented in this table. For example, Minidoka County had a population reduction of 0.9 percent during the period 1940-1950, and an increase of 47.1 percent during the period 1950-1960. During the 1950's, more than 120,000 acres of desert land were irrigated by development of Bureau of Reclamation's North Side Pumping Division, Minidoka Project, and by private development.

Table 1.--Population of cities east of Bliss - Snake River Basin

| City | 1940 | 1950 | 1960 | Percentage of Increase | |
|---|---|---|---|---|---|
| | | | | 1940-1950 | 1950-1960 |
| | number | number | number | percent | percent |
| Rexburg | 3,437 | 4,253 | 4,767 | 23.7 | 12.1 |
| Idaho Falls | 15,024 | 19,218 | 33,161 | 27.9 | 72.6 |
| Blackfoot | 3,681 | 5,180 | 7,378 | 40.7 | 42.4 |
| Pocatello | 18,133 | 26,131 | 28,534 | 44.1 | 9.2 |
| Burley | 5,329 | 5,924 | 7,508 | 11.2 | 26.7 |
| Twin Falls | 11,851 | 17,600 | 20,126 | 48.5 | 14.4 |

Table 2.--Population by counties east of Bliss - Snake River Basin

| State and County | 1940 1/ | 1950 1/ | 1960 1/ | Percentage of Increase 1940-1950 | Percentage of Increase 1950-1960 |
|---|---|---|---|---|---|
| | number | number | number | percent | percent |
| Idaho | | | | | |
| Bannock | 34,759 | 41,745 | 49,342 | 20.1 | 18.2 |
| Bingham | 21,044 | 23,271 | 28,218 | 10.6 | 21.3 |
| Blaine | 5,295 | 5,384 | 4,598 | 1.7 | -14.6 |
| Bonneville | 25,697 | 30,210 | 46,906 | 17.6 | 55.3 |
| Butte | 1,877 | 2,722 | 3,498 | 45.0 | 28.5 |
| Camas | 1,360 | 1,079 | 917 | -20.7 | -15.0 |
| Caribou | 2,284 | 5,576 | 5,976 | 144.1 | 7.2 |
| Cassia | 14,430 | 14,629 | 16,121 | 1.4 | 10.2 |
| Clark | 1,005 | 918 | 915 | -8.7 | -0.3 |
| Custer | 3,549 | 3,318 | 2,996 | -6.5 | -9.7 |
| Fremont | 10,304 | 9,351 | 8,679 | -9.2 | -7.2 |
| Gooding | 9,257 | 11,101 | 9,544 | 19.9 | -14.0 |
| Jefferson | 10,762 | 10,495 | 11,672 | -2.5 | 11.2 |
| Jerome | 9,900 | 12,080 | 11,712 | 22.0 | -3.1 |
| Lincoln | 4,230 | 4,256 | 3,686 | 0.6 | -13.4 |
| Madison | 9,186 | 9,156 | 9,417 | -0.3 | 2.9 |
| Minidoka | 9,870 | 9,785 | 14,394 | -0.9 | 47.1 |
| Power | 3,965 | 3,988 | 4,111 | 0.6 | 3.1 |
| Teton | 3,601 | 3,204 | 2,639 | -11.0 | -17.6 |
| Twin Falls | 36,403 | 40,979 | 41,842 | 12.6 | 2.1 |
| Subtotal | 218,778 | 243,247 | 277,183 | 11.2 | 14.0 |
| Wyoming | | | | | |
| Lincoln | 10,286 | 9,023 | 9,018 | -12.3 | -0.1 |
| Teton | 2,543 | 2,593 | 3,062 | 2.0 | 18.1 |
| Subtotal | 12,829 | 11,616 | 12,080 | -9.5 | 4.0 |
| TOTAL | 231,607 | 254,863 | 289,263 | 10.0 | 13.5 |

1/ Estimated population outside of basin, Caribou 60 percent, Custer 54 percent, in Idaho; Lincoln County, Wyoming 52 percent. These adjustments make the 1960 population in the Snake Basin above King Hill 280,000 (rounded).

## Introduction and General Description

### SCOPE OF INVESTIGATION

Results of this appraisal of the overall proposition of artificial recharge are of a very general, undetailed, and reconnaissance nature. It is not possible to arrive at specific projections, in localized areas, of the effects of large-scale artificial recharge over many years. The underground water resource and related uses occur in an area of over 13,000 square miles, where multimillions of acre-feet of water are carried each year in natural or man-made channels and through a number of aquifers. These aquifers are interconnected with each other, and to a degree, with the water courses on the ground surface. Water movement through the area is subject to an ever-changing, complicated and expanding pattern of consumptive and nonconsumptive water uses.

The ground-water resources of the Snake River Plain have been under almost continual investigation and use for the past 50 years. A modern, overall appraisal was made of this resource by the Ground Water Branch of the Geological Survey, in connection with a joint Bureau of Reclamation-Corps of Engineers Upper Snake River Basin investigation completed and reported on as part of Volume III, Part 2, in 1961. Within the Snake Plain, as a whole, several thousand wells have been drilled by private initiative in recent years. A number of test and observation wells were drilled as a part of the basin study to provide factual data at key locations. Infiltration tests including some augering and diamond drilling were conducted for this reconnaissance. Basic streamflow data in the form of long-term records are available at all of the key points of inflow and diversion from the Snake River and its tributaries.

Although projections on the effect of ground-water recharge cannot be made precisely in localized situations, results and determinations presented in this reconnaissance grade study are founded on a broad base of factual data. In assessing a ground-water situation, there must always be a degree of speculation in arriving at results. Nevertheless, the general findings of this investigation are founded on appreciation of proven analytical processes, observations, and recorded information.

Practical recharge possibilities from a physical and engineering viewpoint were identified, and usable surplus water was related to these possibilities. More thorough analysis was then made of several locations selected because of their favorable characteristics. The possibilities analyzed are for diverting surplus water from Henrys Fork and Snake River and delivering it to the St. Anthony, Idaho Falls, and Idaho Falls-Blackfoot Gravel Pit Recharge areas. Field infiltration rate tests were made in the St. Anthony and Idaho Falls area, since there were no data available on the rates at which water would move from the surface to the regional water table. Engineering plans and estimates at reconnaissance grade standards were prepared, and the cost of delivering recharged water to the individual areas was estimated. For the most part, existing topographic and geologic data were utilized in

estimating the costs involved. A field inspection was made of each of the principal diversion routes to determine rights-of-way, relocations, and any specific structure requirements. Other identified possibilities were described, but were not studied in detail, since they did not offer sufficient promise to warrant the study.

Coordinated hydrologic studies of the Upper Snake River Basin were available from concurrent and earlier specific project and basin-wide investigations. From these studies, amounts of water with no identified requirement and hence useful for recharge were estimated at each location. Utilizing the factual data and analytical results determined by the Geological Survey, as applied to volumes of recharged water, benefits to existing and future irrigation and power were estimated. Data available from economic studies of other projects in Upper Snake Basin were applied in determining irrigation benefits. No new land-quality investigations were made specifically for the recharge study, but the general character of lands in the Upper Snake River Basin is well known from many separate studies. Areas now irrigated by ground and surface water were developed by updating the Upper Snake River Basin results with information from field observation, public utilities, and the Department of Agriculture. The Corps of Engineers provided estimates relating to the flood-control aspects of project.

## PREVIOUS INVESTIGATIONS

Over the past 50 years, considerable information has been gathered on the characteristics of the water resources, present uses of water, and geology in the project area. Topographic coverage of portions of the Snake River Plain is available, and there are completed soil surveys and other technical appraisals for certain localities. Elevations have been extended to many wells in the area under a cooperative program with the State of Idaho and the U. S. Geological Survey. Results of test and observation well drilling are available at key locations in the plain.

All previous investigations of the Snake River Plain were inventoried and reanalyzed as a part of the Bureau of Reclamation-Corps of Engineers Upper Snake River Basin study conducted 1955 through 1960. The results of the various investigations, including a discussion of the Snake Plain Recharge Project, were incorporated in Volume I of the Upper Snake River Basin "Summary Report," which was completed in 1961. The U. S. Geological Survey documented the ground-water data in the Snake River Plain as a part of the basin investigation. This ground-water report, printed as Volume III, Part 2, of the Upper Snake River Basin Report, is entitled, Coordination and Reports of Cooperating Agencies - U. S. Geological Survey - Ground Water Branch.

## P R O B L E M S   A N D   N E E D S   O F   T H E   A R E A

The water in Snake River Basin east of Bliss is now used to a great degree, and the combination of present and future water-use requirements for all purposes, irrigation, fish and wildlife, recreation, municipal, industrial, and power will place even heavier demands on the supply.

In the recent Bureau of Reclamation-Corps of Engineers Basin evaluation, future irrigation potential requirements in the Snake River Basin above Bliss totaled some 580,000 acres of new land and 860,000 acres of land requiring a supplemental water supply. This potential irrigation draft on the water supply represents a diversion requirement of some 2,750,000 acre-feet and a depletion of 1,160,000 acre-feet. However, there appears to be a sufficient water supply in the Upper Snake River Basin for all present and future needs, provided excess runoff from periods of high flows is retained for use during the seasons and years when water is not otherwise available.

Many complex water-supply considerations are fundamental to any further substantial expansion of irrigation in Upper Snake Basin. Use of surplus ground and surface waters will have to be flexibly coordinated, particularly in dry years. It is in this companion use of ground and surface supplies that artificial recharge has its most important long-range application. In years of abundant runoff, excess surface water would be artificially introduced underground to augment and stabilize ground-water supplies. In dry years, when surface supplies are inadequate for existing and future uses, ground water would be pumped and used to supplement the water supply. In order for the ground water to be an effective dry-year water supply for new uses, some exchange between the ground water and existing surface supplies would be involved.

### IRRIGATION

There are about 2,365,000 acres of land irrigated in the Snake River Basin above Bliss. Of this total, approximately 1,750,000 acres are irrigated by surface water. In dry years, or in years of less than normal runoff, a substantial percentage of this acreage suffers from water shortage. Over a 24-year period (1919-1942), the accumulated total shortage of irrigation water above Milner is estimated to be at least 3,400,000 acre-feet.

Since natural flows of Snake River and its tributaries are fully appropriated during the low-flow periods in mid-summer in every year, and since the entire flow of the river above Milner is appropriated through use of existing reservoirs in years when there is less than normal runoff, there is a need for a new source of water to supplement the present surface supplies and to help overcome present shortages.

need new storage

## Problems and Needs of the Area

It is estimated that increased inflow to Snake River above Milner resulting from artificial recharge would provide supplemental water, decreasing the annual irrigation shortages by perhaps 30,000 acre-feet over a 30-year period of study. Under future conditions of development above Milner, the annual decrease in irrigation shortages resulting from recharge as studied in this report would be some 16,000 acre-feet over the same period of study.

An estimated 615,000 acres of land are presently being irrigated by ground water in the Snake River Basin above Bliss, utilizing about 2,000,000 acre-feet of water each year. In addition, 40,000 to 50,000 acres of new land, on the average, are being brought under irrigation by ground water pumping in this area each year. This continued ground-water development in the plain presumably will continue until most of the suitable lands within economic limits from ground water are irrigated.

The rate of decline in the water table of the Snake Plain aquifer has been, and probably will continue to be relatively low because of the large amount of water in storage and the high coefficient of transmissibility. Nevertheless, this decline will continue in proportion to increases in withdrawals, and any additional recharge to ground water, such as the diversion of surplus flows from Henrys Fork and Snake River, would have a beneficial compensating effect on expanding withdrawals of ground water for irrigation and municipal use.

The U. S. Geological Survey recently conducted a study in which the probable rate of water table drawdown associated with the withdrawal of large quantities of ground water from five places on the Snake River Plain was computed. These computations were made for the purpose of judging drawdown in areas where ground water might be developed as a new water supply, mostly for use in dry years as an exchange of replacement basis. These studies give general indications of the effect on drawdown that might be experienced from continued expansion of ground-water development that is now taking place on Snake River Plain. Primary study conditions were: (1) 50 wells spaced at intervals of 1,000 feet along a line about 10 miles long; (2) each well pumped at a rate of 2,250 gallons per minute (about 5 c.f.s.); (3) the wells pumped 122 days and at the same time each year; (4) none of the water returning to the aquifer within the pumped area.

The computed theoretical drawdown along the line of wells for the area studied is:

R 2/64

| Pumping Area | Drawdown in Wells at End of First Pumping Season (feet) | Drawdown in Wells at End of 50 Pumping Seasons (feet) |
|---|---|---|
| Wendell | 6 to 10 | 7 to 11 |
| Shoshone-Dietrich and Eden | 7 to 11 | 10 to 13 |
| Idaho Falls | $3\frac{1}{2}$ to $4\frac{1}{2}$ | 7 to 8 |
| Market Lake-Plano | $3\frac{1}{2}$ to $4\frac{1}{2}$ | 5 to 6 |

These drawdowns are for the aquifer immediately adjacent to the wells; drawdowns in the wells would be greater by the amount of well loss, which generally averages about one foot. Doubling the withdrawal in an area would also double the average drawdown.

These factors, combined with realization that surface-storage sites are becoming more scarce and costly, emphasize the desirability of utilizing surplus seasonal and floodflows by diverting them into infiltration areas to recharge the Snake Plain aquifer.

## FLOOD CONTROL

In past years, floodflows on Teton River, lower Henrys Fork, and Snake River have damaged irrigated farmlands, rural residences, roads, highways, bridges, irrigation and drainage works, community residences and businesses, and other improvements, as well as being a threat to life. In addition, floods involve costs for flood fighting, evacuation, and relief.

The diversion of floodflows from Henrys Fork and Snake River to infiltration areas would provide a measure of flood control by reducing peak flows in the amount of the diversion.

## POWER

Power demand in the Upper Snake River Basin is expanding for many reasons, including irrigation pumping, population increases, increased per capita power consumption, and industrial expansions. Any significant expansion of irrigation in Snake Basin will require pumping to develop and deliver a water supply to the points of use. Pumping directly from ground water, pumping to raise water to lands above the source of water that will be gravity irrigated, and lifting ground water for exchange and replacement purposes are all involved.

The Federal Power Commission estimates that, on the average, power demands will increase by 1,761,000 kilowatts by 1980 in the

general area of the Snake River Basin. Average annual energy requirements are expected to increase by an estimated 11,283,000,000 kilowatt-hours during the same period. These future power loads are based on requirements of southern and eastern Idaho, a part of eastern Oregon, and a small area in western Wyoming.

Power needs of the region are now almost entirely met from the output of hydroelectric plants. Installed generating capacity on Snake and Malad Rivers between and including the American Falls and Oxbow Plants of the Idaho Power Company total about 909,445 kilowatts. Capacity in this latter group, including those on Malad River, total 307,880 kilowatts.

The ground-water outflow from the aquifer of Snake River Plain is of great importance to power production in this reach of river. It constitutes almost the entire water source during low flow periods for the plants between and including C. J. Strike and Twin Falls. The low streamflows, seasonally, and in dry years, coincide with peak irrigation power demands. Hence, any recharge action to maintain or augment outflow from the springs, particularly in dry years and during the latter portion of the irrigation season, correspondingly improves power production in a number of plants. Some part of this improvement could be expected at a time when present and future irrigation pumping power needs are greatest.

## REGIONAL AND LOCAL INTEREST

Over the past several years, local groups and persons have shown much interest in and support for artificially recharging ground water in the Snake River Plain. Such interest was evident at a Public Hearing held by the Corps of Engineers at Idaho Falls, Idaho in 1955. Ground-water irrigators in the Mud Lake region have expressed a firm interest in using surplus Snake River flows for recharge. In the public hearings held in Idaho Falls, Idaho, on December 7, 1960, on the Upper Snake River Basin "Preliminary Summary Report," Chamber of Commerce groups, other community organizations, and interested water users indicated continued support for studies on the Snake Plain Recharge Project. Since that time, there have been further indications of local and regional interest in such a development.

# ACKNOWLEDGMENTS

During the course of this investigation, use has been made of information and data gathered by other agencies and individuals. The principal Federal agencies that have contributed to the information used are the Geological Survey, Corps of Engineers, Coast and Geodetic Survey, Fish and Wildlife Service, Soil Conservation Service, Atomic Energy Commission (National Reactor Testing Station), U. S. Public Health Service, and Weather Bureau.

Information from various State agencies, public utilities, private organizations, and individuals in the development area concerning ownership, economic conditions, water supply, water rights, and water use has been important to this study and is appreciated.

Ground-water geologic and hydrologic relationships are of paramount importance in considering the general proposition of recharge, and the determinations relating to this phase of the investigation were made cooperatively by the Bureau of Reclamation-Ground Water Branch of the U. S. Geological Survey. This report could not have been prepared without this aid and cooperation, which are gratefully acknowledged. Information relating to the existing geologic and ground-water situation in the Snake River Plain, the passage of water from the surface of the ground to join the regional ground water, the physical behavior of recharged water within the aquifer, and the postulated effects of recharge on the overall ground-water resource in the Plain was developed by the Geological Survey. A report by that agency is appended.

W A T E R

Land and water are considered the most important natural resources in the Snake River Basin, and with present storage facilities this water supply is almost completely utilized in periods of low runoff. Irrigation and other water shortages occur during these periods, and any substantial increased water utilization will depend upon further storage development, either surface impoundment or underground, to more fully utilize that portion of this resource that now passes Milner Dam unused in years of average or above average runoff.

Irrigation in the Basin above Bliss contributes substantially to the Basin economy. It has been practiced since about 1880, and has continued as the stabilizing influence in the area. Some 2.4 million acres are now irrigated in the Basin above Bliss, and thousands of acres of potentially irrigable dry lands would benefit from irrigation if the available water could be stored for use during the irrigation season.

Lands presently irrigated and potentially irrigable dry lands in the Basin above Bliss are summarized in table 3.

Table 3.--Summary of irrigated and potentially irrigable lands in Snake Basin above Bliss

Snake Plain Recharge Project, Idaho

| Item | Land Area (acres) |
|---|---|
| Irrigated Lands | |
| Surface irrigation | 1,750,000 |
| Ground-water pumping | 615,000 |
| Subtotal | 2,365,000 |
| Potentially Irrigable Dry Lands | 580,000 1/ |
| TOTAL | 2,945,000 |

1/ An available water supply, either surface or ground water, was associated with these lands in the 1961 Upper Snake River Basin Report.

## DEVELOPMENT FOR SURFACE WATER USES

At King Hill, Idaho, the Snake River Basin has a surface drainage of 35,800 square miles. Drawing No. 932-OA-125-22 illustrates streamflow quantities at key measuring points in the basin. Snake River, which flows along the south margin of Snake River Plain, is the trunk stream in the basin. Its flow is maintained by perennial streams from the north, east, and south, and ground-water inflows.

Since about 1879, when simple structures first diverted water from tributaries of Snake River onto the Snake River Plain, the Snake Basin above Bliss has become an agricultural production area of some 2,365,000 irrigated areas with national importance.

Following the usual pattern of irrigation development in the west, those lands that could be irrigated by simple gravity diversion and natural streamflow were brought into production first. With the demand for more water during dry years and the desire to irrigate additional land, storage reservoirs were constructed. An intricate system of operation for the entire Snake River Basin above Bliss has developed as a result of the continuing process of expansion and improvement in water and land use. The gravity-served irrigated lands above American Falls were in production by 1900. Below American Falls, where costly diversion works and canals were required, large areas were brought under irrigation between 1900 and 1920. Since 1920, the limited storage of early years has been substantially increased by additional reservoirs, and there has been some extension of surface-water irrigation, mostly in the Michaud Flats and Minidoka Northside areas. The extent and location of gravity-irrigated land in this area are shown on the General Map.

Over the years, Snake River flow above King Hill has been controlled by constructing storage facilities. Those storage and regulatory reservoirs having a capacity of at least 5,000 acre-feet above King Hill are:

| Reservoir | Total Capacity (acre-feet) |
|---|---|
| Jackson Lake | 847,000 |
| Palisades | 1,401,600 |
| Grassy Lake | 15,451 |
| Henrys Lake | 83,200 |
| Island Park | 127,600 |
| Grays Lake | 100,000 |
| Blackfoot-Marsh | 413,000 |
| Portneuf-Marsh Valley | 23,695 |
| American Falls | 1,700,000 |
| Lake Walcott (normal operation) | 210,180 |

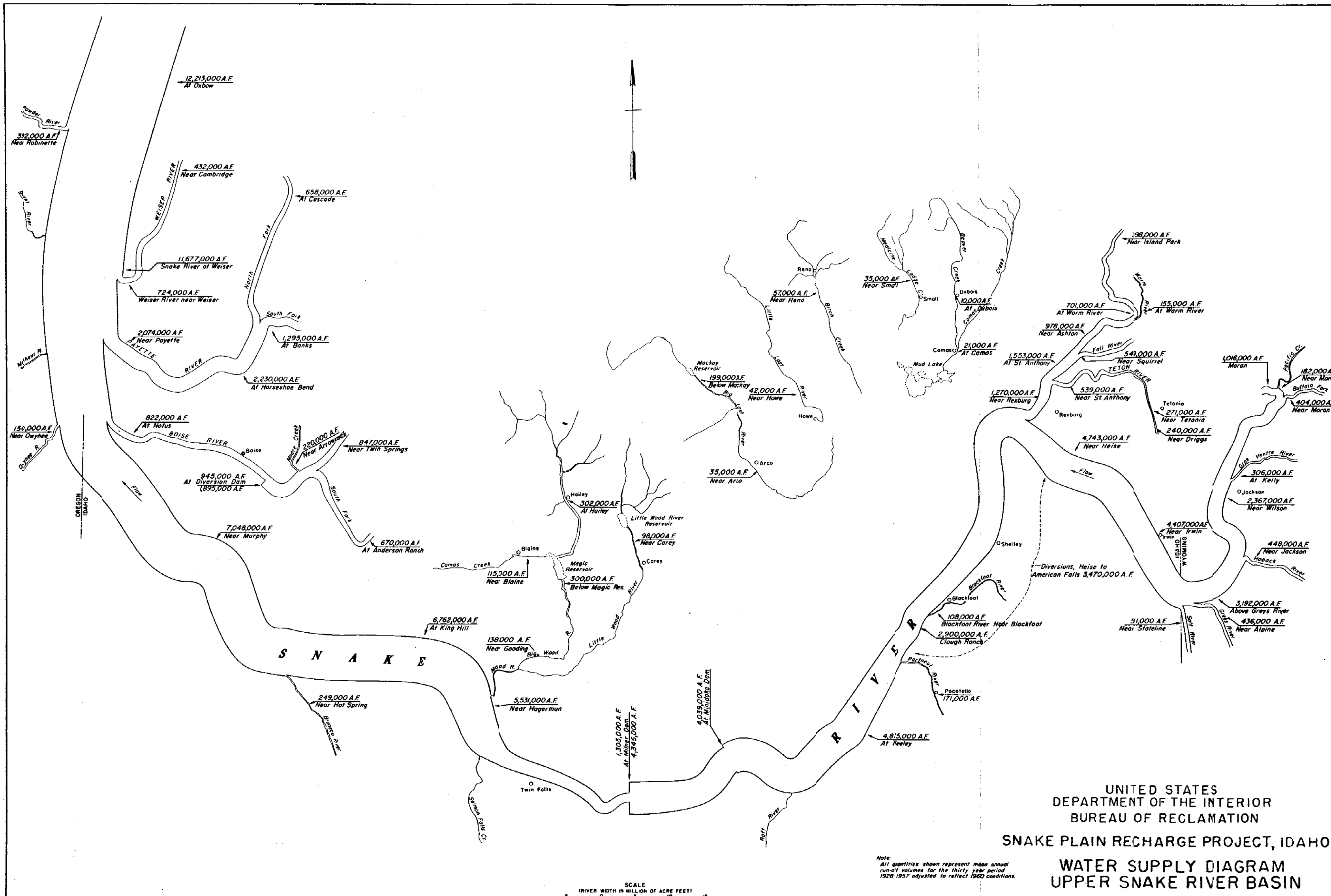
| Reservoir (continued) | Total Capacity (acre-feet) |
|---|---|
| Lower Goose Creek (Oakley) | 74,350 |
| Milner Lake | 80,000 |
| Wilson Lake | 18,500 |
| Murtaugh Lake (Dry Creek) | 12,000 |
| Mud Lake | 61,600 |
| Mackay | 44,495 |
| Cedar Creek | 26,000 |
| Fish Creek | 14,411 |
| Little Wood | 30,000 |
| Magic | 192,000 |
| Salmon Falls Creek | 230,650 |
| Twin Lakes | 31,240 |
| Lower Salmon | 5,200 |

The Snake River and its tributaries above Bliss are also being utilized for the production of power. Hydro powerplants with capacities in excess of 5,000 kilowatts in this area are shown on the General Map, and listed as follows:

| Powerplant | Capacity (Kilowatts) |
|---|---|
| Bliss | 75,000 |
| Lower Malad | 13,500 |
| Upper Malad | 7,200 |
| Lower Salmon | 60,000 |
| Upper Salmon, Nos. 1, 2, 3, and 4 | 34,500 |
| Thousand Springs | 8,000 |
| Shoshone Falls | 10,880 |
| Twin Falls | 13,500 |
| Minidoka | 13,400 |
| American Falls | 27,500 |
| Palisades | 114,000 |
| Ashton | 5,800 |

In addition to irrigation and power production, the domestic water supply for a population of 280,000 people is obtained from surface flows or ground water in this area. Water needs for industrial uses such as mineral processing, the processing of agricultural products, and requirements of the National Reactor Testing Station, plus a variety of light industries, is continually growing.

Functions such as fish and wildlife, recreation, and pollution abatement also place requirements upon surface flows and ground water in the area.




Note
All quantities shown represent mean annual run-off volumes for the thirty year period 1928-1957 adjusted to reflect 1960 conditions.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

SNAKE PLAIN RECHARGE PROJECT, IDAHO

WATER SUPPLY DIAGRAM
UPPER SNAKE RIVER BASIN

Jan. 1960

932-0A-125-22

PLATE II-5

| Reservoir (continued) | Total Capacity (acre-feet) |
|---|---|
| Lower Goose Creek (Oakley) | 74,350 |
| Milner Lake | 80,000 |
| Wilson Lake | 18,500 |
| Murtaugh Lake (Dry Creek) | 12,000 |
| Mud Lake | 61,600 |
| Mackay | 44,495 |
| Cedar Creek | 26,000 |
| Fish Creek | 14,411 |
| Little Wood | 30,000 |
| Magic | 192,000 |
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| Upper Salmon, Nos. 1, 2, 3, and 4 | 34,500 |
| Thousand Springs | 8,000 |
| Shoshone Falls | 10,880 |
| Twin Falls | 13,500 |
| Minidoka | 13,400 |
| American Falls | 27,500 |
| Palisades | 114,000 |
| Ashton | 5,800 |

In addition to irrigation and power production, the domestic water supply for a population of 280,000 people is obtained from surface flows or ground water in this area. Water needs for industrial uses such as mineral processing, the processing of agricultural products, and requirements of the National Reactor Testing Station, plus a variety of light industries, is continually growing.

Functions such as fish and wildlife, recreation, and pollution abatement also place requirements upon surface flows and ground water in the area.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

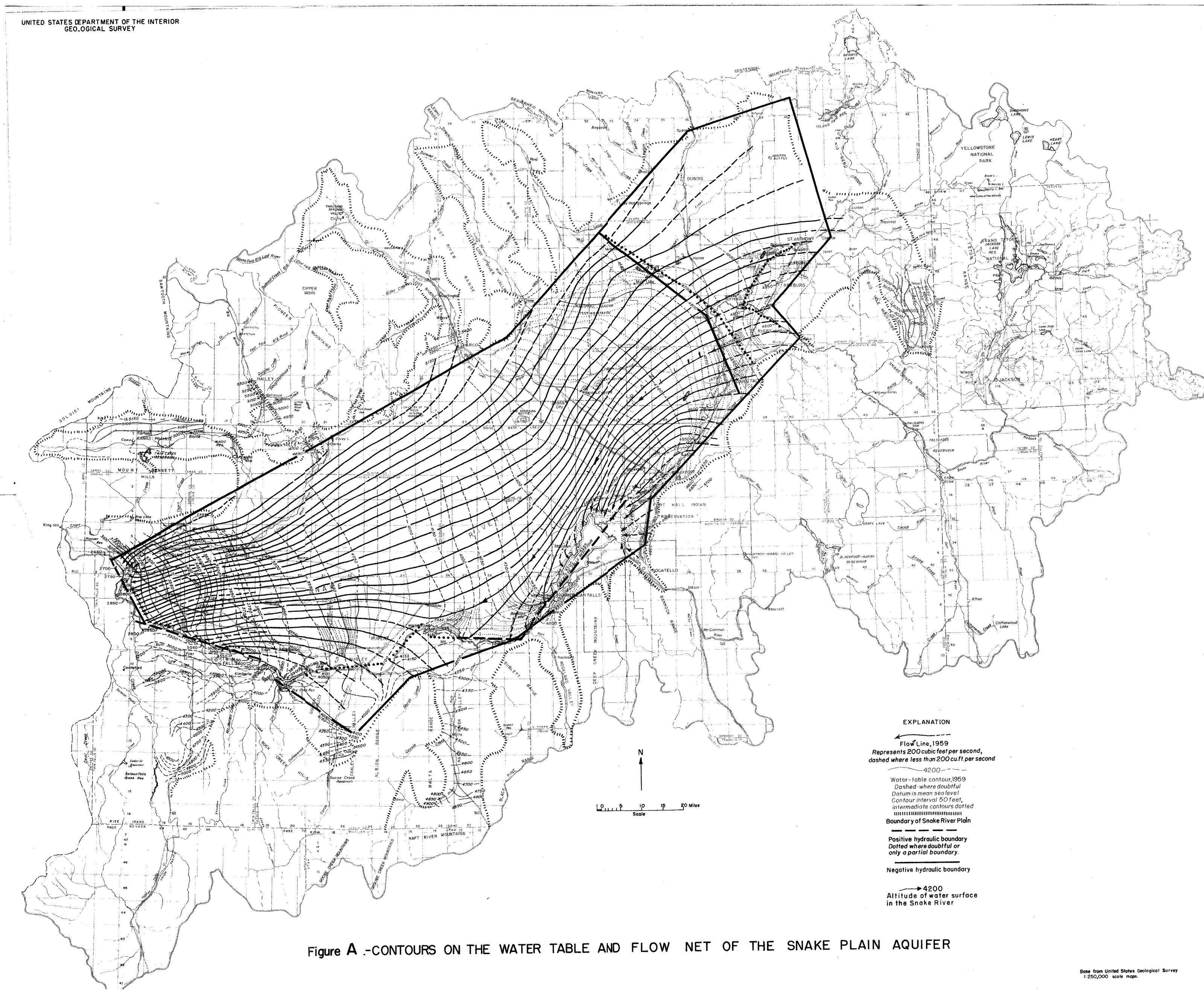



Figure A.-CONTOURS ON THE WATER TABLE AND FLOW NET OF THE SNAKE PLAIN AQUIFER

Base from United States Geological Survey 1:250,000 scale maps.

area has taken place since 1950. Of the 135,000 acres irrigated by ground water in the Minidoka Northside area over 60,000 acres are included in the Bureau of Reclamation's North Side Pumping Division, Minidoka Project. The Raft River-Oakley Fan area is located south of Snake River in the Raft River and lower Goose Creek Basins. This area includes the lands irrigated by ground water south of Murtaugh Lake.

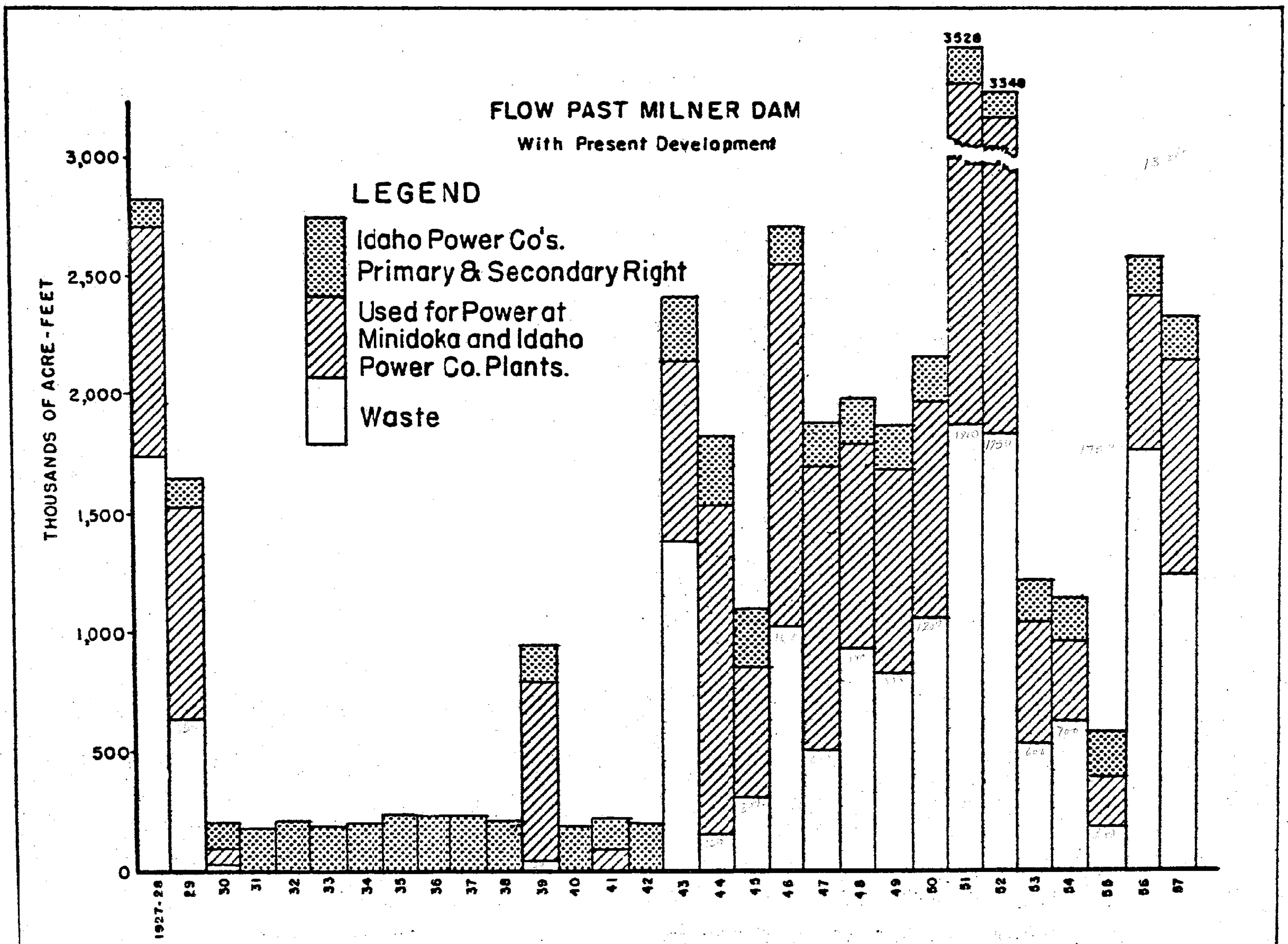
The National Reactor Testing Station was established in mid-1949 on the desert between Arco and Idaho Falls by the Atomic Energy Commission to build, test, and operate various types of nuclear equipment. The N.R.T.S. covers some 572,000 acres of sagebrush land on the Snake River Plain, in parts of Butte, Bingham, Bonneville, and Jefferson Counties. The total water requirements of this very large and important activity are met by pumping from the aquifers of the Snake River Plain.

## WATER RESOURCES

The water available for diversion for the Snake Plain Recharge Project is only that water which wastes past Milner Dam in excess of the capacities of powerplants in this general reach of Snake River. The Idaho Power Company rights at American Falls Reservoir and the hydraulic capacities of the Minidoka and Twin Falls powerplants were considered in determining divertible flows. Water passing Milner Dam is used as an index of water excess to Upper Snake River Basin irrigation needs, since gains in the river below Milner are generally large enough to satisfy all downstream irrigation requirements.

At times, water must be released past Milner Dam to satisfy downstream power rights. In this study, water was not considered divertible for recharge unless, in addition to satisfying all irrigation needs, both Minidoka and Twin Falls Powerplants were operating at their hydraulic capacities of 4,800 c.f.s. and 910 c.f.s., respectively. This would result in quite high plant factors at other downstream plants above Brownlee, since these plants are sized more or less to accommodate the increased flow in each incremental reach. Exceptions are the peaking plants at Lower Salmon, Bliss, and C. J. Strike, which operate at relatively low plant factors under present conditions.

From studies representative of present level of development, waters passing Milner Dam during the 1928-57 period were determined. These annual flows and their component parts are illustrated on Drawing No. 832-125-340.



FLOW PAST MILNER DAM
With Present Development
LEGEND
Idaho Power Co's. Primary & Secondary Right
Used for Power at Minidoka and Idaho Power Co. Plants.
Waste
THOUSANDS OF ACRE-FEET
3,000
2,500
2,000
1,500
1,000
500
0
3528
3348
1927-28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
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56
57

832-125-340

## Surface Water Supply

Water divertible for recharge has been considered under conditions of present development, present development with the addition of Burns Creek and Teton Basin Project, and conditions with future development.

Records of runoff used in this study have been taken from U. S. Geological Survey Water Supply Papers and the Annual Water Distribution and Hydrometric Work, District No. 36, Snake River, Idaho. The Supporting Data for Palisades Dam, Snake River and Henrys Fork sections have also been used to determine surplus waters under the present level of development. Total volumes passing Milner were reduced by the amount of flow required for maximum energy production at the Minidoka and Twin Falls hydroelectric plants. The remainders, called Milner Spills, Present Conditions, are shown on table 5. Surplus waters are not available during the July through December months. Tables of spills and divertible flows are therefore limited to the January-June period.

The effect of the potential Teton Basin Project on the above Milner Spills was based on the change in flow of the Henrys Fork near Rexburg between present and project conditions. An additional adjustment was made to include the effect of the possible Burns Creek development. Milner Spills, Present Conditions, plus Teton Basin Project and Burns Creek, are shown on table 6.

Supporting data for the Upper Snake River Basin joint Bureau of Reclamation-Corps of Engineers 1961 Report were used to determine surplus waters with future development. The future development possibilities described in this report cover some 80 single- and multiple-purpose projects involving 46 new reservoirs with a combined active capacity of 7,044,000 acre-feet, and 20 new powerplants with a total installed capacity of 1,241,500 kilowatts. As under present development, surplus volumes were modified to provide maximum generation at Minidoka and Twin Falls plants. Milner Spills, Future Conditions, are shown on table 7.

## Quality of Water

The quality of the Snake River Plain aquifer waters for irrigation was tested during 1947 and 1948 as a part of the investigations for the North Side Pumping Division of the Minidoka Project. All tests from nine wells which tapped the regional ground-water aquifer indicated the water as Class I irrigation water. The range of results is shown in table 8. These underground waters have been used without deleterious effect since then to develop over 60,000 acres of the North Side Minidoka Pumping Division. About 420,000 acres of land use the waters of the Snake Plain aquifer for irrigation through ground-water pumping.

Table 5.--Milner Spills[1/] - Present Conditions
Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | 106 | 199 | 885 | 481 | 71 | 1742 |
| 1929 | | | 112 | 202 | 319 | | 633 |
| 1930 | | | | 29 | | | 29 |
| 1931-38 | | No | Spill | | | | |
| 1939 | | | | 34 | | | 34 |
| 1940-42 | | No | Spill | | | | |
| 1943 | | | | 1000 | 215 | 165 | 1380 |
| 1944 | | | | | | 149 | 149 |
| 1945 | | | | | | 307 | 307 |
| 1946 | | 89 | 294 | 463 | 163 | 10 | 1019 |
| 1947 | | 9 | 239 | 238 | | 11 | 497 |
| 1948 | | | 51 | 299 | 311 | 261 | 922 |
| 1949 | | | | 453 | 359 | | 812 |
| 1950 | | | | 706 | 156 | 190 | 1052 |
| 1951 | 62 | 363 | 270 | 758 | 426 | | 1879 |
| 1952 | 86 | 283 | 376 | 471 | 569 | 47 | 1832 |
| 1953 | | | 138 | 163 | | 234 | 535 |
| 1954 | | | 123 | 504 | | | 627 |
| 1955 | | | | 186 | | | 186 |
| 1956 | | 43 | 272 | 783 | 375 | 286 | 1759 |
| 1957 | | | | 450 | 479 | 306 | 1235 |

Total Spills during 1928-57 = 16,600,000 acre-feet
Average Spill during 1928-57 = 553,000 acre-feet

1/ Water in excess of irrigation requirements above Milner and in excess of Minidoka, Twin Falls and Shoshone Falls powerplant capacities.

Table 6.--Milner Spills with Burns Creek & Teton Basin Project
Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 181 | 904 | 367 | 32 | 1484 |
| 1929 | | | 32 | 199 | 341 | | 572 |
| 1930-42 | | No | Spill | | | | |
| 1943 | | | | 859 1/ | 157 | 127 | 1143 |
| 1944 | | No | Spill | | | | |
| 1945 | | | | | | 4 | 4 |
| 1946 | | | 287 | 424 | 115 | | 1126 |
| 1947 | | | 154 | 230 | | | 384 |
| 1948 | | | | 172 | 255 | 210 | 637 |
| 1949 | | | | 412 | 227 | | 639 |
| 1950 | | | | 589 | 124 | 138 | 851 |
| 1951 | | 364 | 279 | 746 | 361 | | 1750 |
| 1952 | | 271 | 391 | 473 | 454 | | 1589 |
| 1953 | | | 46 | 169 | | 169 | 384 |
| 1954 | | | 62 | 478 | | | 540 |
| 1955 | | | | 58 | | | 58 |
| 1956 | | | 195 | 772 | 317 | 284 | 1568 |
| 1957 | | | | 431 | 426 | 235 | 1092 |

Total Spill during 1928-57 = 13,800,000 acre-feet
Average Spill during 1928-57 = 460,000 acre-feet

1/ 100 deducted for refill of Burns Creek.

Table 7.--Milner Spills, 1/ Future Conditions
Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 39 | 821 | 186 | | 1046 |
| 1929 | | | 3 | 9 | 58 | | 70 |
| 1930-42 | | | No | Spill | | | |
| 1943 | | | | 141 | | | 141 |
| 1944 | | | 102 | 75 | | | 177 |
| 1945 | | | No | Spill | | | |
| 1946 | | | 110 | 481 | 57 | | 648 |
| 1947 | | | | 405 | | | 405 |
| 1948 | | | | 223 | 85 | | 308 |
| 1949 | | | | 179 | 69 | | 248 |
| 1950 | | | | 936 | | | 936 |
| 1951 | | 228 | 263 | 944 | 184 | | 1619 |
| 1952 | | 2 | 45 | 898 | 285 | | 1230 |
| 1953-55 | | | No | Spill | | | |
| 1956 | | 81 | | 295 | 132 | 61 | 569 |
| 1957 | | | | 433 | 219 | 66 | 718 |

Total Spill during 1928-57 = 8,100,000 acre-feet
Average Spill during 1928-57 = 270,000 acre-feet

1/ Water in excess of irrigation requirements above Milner and in excess of Minidoka, Twin Falls, and Shoshone Falls Powerplant capacities.

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Table 8.--Water quality analysis

| Limiting Factors | Standards for Class I: Water | Ground Water 1/ | Snake River 2/ Heise Min. | Heise Avg. | Heise Max. | King Hill Min. | King Hill Avg. | King Hill Max. |
|---|---|---|---|---|---|---|---|---|
| | Less Than | | | | | | | |
| Conductance K x $10^6$ at 25° C. | 750 | 320-580 | 290 | 362 | 610 | 472 | 511 | 551 |
| Boron p.p.m. | 0.33 | 0.02-0.12 | 0.03 | 0.05 | 0.09 | 0.02 | 0.06 | 0.12 |
| Sodium percentage | 60 | 17-36 | 9 | 11 | 17 | 23 | 25 | 28 |
| Chlorides (E.P.P.M.) | 5.0 | 0.42-1.25 | 0.16 | 0.28 | 1.02 | 0.59 | 0.68 | 0.73 |

1/ 1947-1948 tests on 9 wells for Unit B, North Side Pumping Division, Minidoka Project. These wells tap the Snake Plain Aquifer.

2/ For 1956-57 water year, from Quality of Surface Waters for Irrigation, Western United States, 1957, U. S. Geological Survey, Water Supply Paper No. 1524, average values are weighted average.

Since 1951, the U. S. Geological Survey has published data on the "Quality of Surface Waters for Irrigation, Western United States." Included in table 8 are data from the 1957 Water Supply Paper, No. 1524, for the stations Snake River near Heise and at King Hill. These stations are representative of the inflow and outflow, respectively, of the Snake Plain Aquifer. Comparison of the extremes for these stations shows the averaging or leveling off effect of the aquifer. The weighted average shows the increase in concentration of salts from the use and re-use of water over and over again for irrigation. However, even the extremes are within the limits established for Class 1 water. A large part of this irrigation water percolates to the water table and recharges the Snake Plain Aquifer. The proposed recharge system would dilute this concentration of salts since only the high flows of the river would be diverted. These high flows have minimum amounts of salts due to dilution and the small amount of reuse of large flows for irrigation.

## WATER RIGHTS

It is proposed to divert for recharge only flows in excess of all existing and future irrigation or storage requirements. However, a permit from the Idaho State Reclamation Engineer would be required for flood flow diversion at each location. These permits would need to contain restrictions that would not allow the recharge use to preclude future direct beneficial water use.

## WATER REQUIREMENTS

### Evaporation

From evaporation records at Aberdeen, Minidoka Dam and Palisades Dam an evaporation-elevation relationship was established for eastern Idaho. From this relationship, the monthly evaporation from the infiltration ponds was estimated. An evaporation pan was installed at Teton, Idaho in April 1961 to obtain a better index for evaporation from that area. Data obtained to date from this pan tend to substantiate the estimating procedures described above. Annual evaporation from the recharge pools was computed using the evaporation rates for the local pan, adjusted by a pan coefficient of 0.7, and assuming evaporation to continue for three months after diversions cease. Table 9 shows annual diversions, evaporation and net recharge at St. Anthony for each of the 19 years when surplus flows were available. Total evaporation during the 19 years amounts to about $2\frac{1}{2}$ percent of the total diversions. With much less terminal evaporation, and less than one-half the surface area, total evaporation at Idaho Falls is estimated to be one percent of total diversions.

### Seepage

Seepage is not a problem in the recharge plan. Any canal losses through seepage prior to reaching the recharge areas will eventually reach the Snake Plain aquifer. Such seepage could be beneficial in the St. Anthony area where subirrigation is practiced, since recharge diversions would be made primarily during the period when farmers are "bringing up the sub" in the Egin Bench area.

### Sedimentation

Four series of sediment measurements were made on Henrys Fork at St. Anthony in 1960. The results are summarized below.

| Date | Flow c.f.s. | Suspended Solids p.p.m. |
|---|---|---|
| 4/12/60 | 2,920 | 80 |
| 5/12/60 | 3,570 | 59 |
| 6/6/60 | 3,650 | 23 |
| 7/7/60 | 1,010 | 20 |

Using these data, and an annual diversion of 100,000 acre-feet, the deposition of sediment in the St. Anthony infiltration fields was computed as about 5 acre-feet per year. While no sedimentation data are available on the main stem of Upper Snake River, the water is

Table 9.--Evaporation from St. Anthony Recharge Fields

| Year | Diversion Season Acre-Feet | Terminal 1/ Acre-Feet | Total Acre-Feet | Total Diversion 1,000 A.F. | Total Recharge 1,000 A.F. |
|---|---|---|---|---|---|
| 1928 | 2,241 | 2,520 | 4,761 | 236 | 231 |
| 1929 | 1,322 | 2,554 | 3,876 | 108 | 104 |
| 1930 | 560 | 2,241 | 2,801 | 15 | 12 |
| 1939 | 560 | 2,241 | 2,801 | 34 | 31 |
| 1943 | 2,241 | 2,520 | 4,761 | 341 | 336 |
| 1944 | 919 | 2,520 | 3,439 | 84 | 81 |
| 1945 | 919 | 2,520 | 3,439 | 100 | 97 |
| 1946 | 1,322 | 2,554 | 3,876 | 224 | 220 |
| 1947 | 560 | 2,241 | 2,801 | 19 | 16 |
| 1948 | 2,241 | 2,520 | 4,761 | 236 | 231 |
| 1949 | 1,322 | 2,554 | 3,876 | 158 | 154 |
| 1950 | 2,241 | 2,520 | 4,761 | 193 | 188 |
| 1951 | 1,322 | 2,554 | 3,876 | 280 | 276 |
| 1952 | 2,241 | 2,520 | 4,761 | 356 | 351 |
| 1953 | 560 | 2,241 | 2,801 | 39 | 36 |
| 1954 | 560 | 2,241 | 2,801 | 28 | 25 |
| 1955 | 560 | 2,241 | 2,801 | 24 | 21 |
| 1956 | 2,241 | 2,520 | 4,761 | 250 | 245 |
| 1957 | 2,241 | 2,520 | 4,761 | 206 | 201 |

1/ Terminal evaporation computed at full rate for two months following diversions, and at 50% rate for third month.

relatively clean and the concentration of dissolved solids would be low, as are those of Henrys Fork at St. Anthony. Annual diversions from Snake River at Great Western Headworks for recharge average about 200,000 acre-feet and the annual sediment load is estimated to be about 10 acre-feet per year.

## WATER UTILIZATION

### Operational Criteria

#### Henrys Fork at St. Anthony

Henrys Fork at St. Anthony is the most upstream diversion point under consideration for the Snake Plain Recharge Project. As such, it would most directly affect the northerly flowlines which discharge into Snake River in Hagerman Valley (see Figure A). It is estimated that of the water diverted at St. Anthony, 65 percent would return in Hagerman Valley with most of the remainder returning as inflow to American Falls Reservoir. Thus, diversions at St. Anthony would be most beneficial in terms of long-range holdover storage, and this site was given first priority in determining availability of flows for diversion.

Divertible flows at St. Anthony were determined for three levels of development: Present, present plus Burns Creek and Teton Basin Project, and future development, as defined in Upper Snake River Basin Report. From an analysis of canal capacity versus total divertible volume, 2,000 cubic feet per second was selected as the optimum canal capacity to the St. Anthony infiltration fields. With a canal capacity of 2,000 cubic feet per second, the divertible flows at St. Anthony under each of the three levels of development described above are shown on tables 10, 11, and 12, respectively. These flows are in excess of present and anticipated use of water, including the lesser of 1,000 c.f.s. or natural flow as requested by the Bureau of Sport Fisheries and Wildlife for fish preservation. Annual diversions for recharge at St. Anthony during the 1928-57 period under present, present plus Burns Creek and Teton Project, and future levels of development would average 100,000, 83,000, and 58,000 acre-feet, respectively.

#### Snake River near Idaho Falls

The recharge area at St. Anthony was given first priority to surplus flows in the river. Consequently, flows divertible at Idaho Falls are depleted by the flows divertible at St. Anthony under corresponding levels of development. Only those flows surplus to all existing and anticipated use of water are assumed divertible.

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Table 10.--Diversions at St. Anthony for recharge with 2,000 c.f.s. canal 1/ - Present conditions
Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | 33 | 42 | 7 | 123 | 31 | 236 |
| 1929 | | | 30 | | 78 | | 108 |
| 1930 | | | | 15 | | | 15 |
| 1931-38 | | No | Spill | | | | |
| 1939 | | | | 34 | | | 34 |
| 1940-42 | | No | Spill | | | | |
| 1943 | | | | 119 | 123 | 99 | 341 |
| 1944 | | | | | | 84 | 84 |
| 1945 | | | | | | 100 | 100 |
| 1946 | | 27 | 36 | 99 | 62 | | 224 |
| 1947 | | | 6 | 13 | | 11 | 30 |
| 1948 | | | 29 | 25 | 123 | 59 | 236 |
| 1949 | | | | 35 | 123 | | 158 |
| 1950 | | | | 47 | 65 | 81 | 193 |
| 1951 | 28 | 33 | 35 | 61 | 123 | | 280 |
| 1952 | 36 | 30 | 38 | 82 | 123 | 47 | 356 |
| 1953 | | | 22 | 17 | | | 39 |
| 1954 | | | 2 | 26 | | | 28 |
| 1955 | | | | 24 | | | 24 |
| 1956 | | 13 | 28 | 49 | 123 | 37 | 250 |
| 1957 | | | | 4 | 123 | 79 | 206 |

Total Divertible during 1928-57 period = 3,000,000 acre-feet
Average Divertible during 1928-57 " = 100,000 acre-feet

1/ With 1,000 c.f.s. for Fish.

Table 11.--Divertible at St. Anthony with 2000 c.f.s. Canal[1/] and Burns Creek and Teton Basin Project
Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 38 | 6 | 123 | 21 | 188 |
| 1929 | | | 30 | | 75 | | 105 |
| 1930-42 | | No | Spills | | | | |
| 1943 | | | | 119 | 123 | 100 | 342 |
| 1944 | | No | Spills | | | | |
| 1945 | | | | | | 4 | 4 |
| 1946 | | | 37 | 102 | 66 | | 205 |
| 1947 | | | | 15 | | | 15 |
| 1948 | | | | 27 | 123 | 63 | 213 |
| 1949 | | | | 28 | 123 | | 151 |
| 1950 | | | | 45 | 62 | 87 | 194 |
| 1951 | | 32 | 33 | 62 | 123 | | 250 |
| 1952 | | 28 | 36 | 84 | 123 | 9 | 280 |
| 1953 | | | 23 | 20 | | | 43 |
| 1954 | | | 3 | 25 | | | 28 |
| 1955 | | | | 26 | | | 26 |
| 1956 | | | 28 | 52 | 123 | 46 | 249 |
| 1957 | | | | 6 | 123 | 80 | 209 |

Total divertible during 1928-57 period = 2,500,000 acre-feet
Average " " " " = 83,000 acre-feet

1/ With 1,000 c.f.s. for Fish.

Table 12.--Divertible at St. Anthony with 2000 c.f.s. Canal[1/]
Future Conditions

Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 38 | 6 | 123 | | 167 |
| 1929 | | | 3 | | 58 | | 61 |
| 1930-42 | | | No | Spills | | | |
| 1943 | | | | 119 | | | 119 |
| 1944-45 | | | No | Spills | | | |
| 1946 | | | 37 | 102 | 57 | | 196 |
| 1947 | | | | 15 | | | 15 |
| 1948 | | | | 27 | 85 | | 112 |
| 1949 | | | | 28 | 69 | | 97 |
| 1950 | | | | 45 | | | 45 |
| 1951 | | 32 | 33 | 62 | 123 | | 250 |
| 1952 | | 2 | 36 | 84 | 123 | | 245 |
| 1953 | | | | | | | |
| 1954 | | | | | | | |
| 1955 | | | | | | | |
| 1956 | | 36 | | 52 | 123 | 46 | 257 |
| 1957 | | | | 6 | 123 | 66 | 195 |

Total divertible during 1928-57 period = 1,750,000 acre-feet
Average " " " " = 58,000 acre-feet

1/ With 1,000 c.f.s. for Fish Release.

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## Water

For this reconnaissance analysis, it was decided to enlarge the Great Western Headworks and Canal. A canal capacity of 2,500 c.f.s. was selected, limited more by infiltration field capacity and canal-size economics than by water supply. Based on the average diversions by Great Western water users, the canal capacity available for recharge diversions would be 2,400 c.f.s. during January through April; 2,100 c.f.s. in May; and 1,900 c.f.s. in June. Assuming a 2,000 c.f.s. canal diverting at St. Anthony, flows divertible for recharge at Idaho Falls under present, present plus Teton Project and Burns Creek, and future levels of development are shown on tables 13, 14, and 15, respectively. Annual diversions during the 1928-57 period would average 200,000, 165,000, and 80,000 acre-feet respectively, under each of the three conditions.

The proposed inlet capacities to the 13 gravel pits in the Idaho Falls-Blackfoot area total about 190 cubic feet per second. These gravel pit recharge areas would be served, for the most part, by existing canals. After considering water requirements of the water users on these canals, it is estimated that annual diversions to the gravel pit areas during the 1928-57 period would average 15,000 acre-feet with present development, and about 10,000 acre-feet with future development.

### Other Possible Sources of Recharge

Water would be divertible from Big and Little Wood Rivers only three percent of the time without reducing power production at Idaho Power Company's Upper and Lower Malad Powerplants. No further investigation was made of this recharge source.

With no diversions upstream from Milner for recharge, an average of about 70,000 acre-feet could be delivered to infiltration fields through the existing Milner-Gooding Canal. Because this area could not be evaluated strictly from the standpoint of contributing water to the main aquifer of the Snake Plain, no detailed analysis of recharge via Milner-Gooding Canal is included in this reconnaissance report.

Estimates of annual quantity of water that would be available for diversions to recharge areas are summarized in table 16.

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Table 13.--Diversions at Idaho Falls for Recharge with 2,500 c.f.s. Canal[1/], Present conditions

Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | 73 | 148 | 143 | 129 | 40 | 533 |
| 1929 | | | 82 | 143 | 129 | | 354 |
| 1930 | | | | 14 | | | 14 |
| 1931-42 | | | | | | | |
| 1943 | | | | 143 | 92 | 66 | 301 |
| 1944 | | | | | | 65 | 65 |
| 1945 | | | | | | 113 | 113 |
| 1946 | | 62 | 148 | 143 | 101 | 10 | 464 |
| 1947 | | 9 | 148 | 143 | | | 300 |
| 1948 | | | 22 | 143 | 129 | 113 | 407 |
| 1949 | | | | 143 | 129 | | 272 |
| 1950 | | | | 143 | 91 | 109 | 343 |
| 1951 | 34 | 133 | 148 | 143 | 129 | | 587 |
| 1952 | 50 | 138 | 148 | 143 | 129 | | 608 |
| 1953 | | | 116 | 143 | | 113 | 372 |
| 1954 | | | 121 | 143 | | | 264 |
| 1955 | | | | 143 | | | 143 |
| 1956 | | 30 | 148 | 143 | 129 | 113 | 563 |
| 1957 | | | | 143 | 129 | 113 | 385 |

Total divertible during 1928-57 period = 6,000,000 acre-feet
Average " " " " = 200,000 acre-feet

1/ With 2,000 c.f.s. Canal Diverting at St. Anthony. The 2,500 c.f.s. Canal is at the Headworks of the Great Western Canal and 2,400 c.f.s. Assumed Usable Jan.-April, 2,100 c.f.s. in May and 1,900 c.f.s. in June.

Table 14.--Divertible at Idaho Falls with 2,500 c.f.s. Canal[1/] with Burns Creek and Teton Basin Project

Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 143 | 143 | 129 | 11 | 426 |
| 1929 | | | 2 | 143 | 129 | | 274 |
| 1930-42 | | | No | Spills | | | |
| 1943 | | | | 143 | 34 | 27 | 204 |
| 1944-45 | | | No | Spills | | | |
| 1946 | | | 148 | 143 | 49 | | 340 |
| 1947 | | | 148 | 143 | | | 291 |
| 1948 | | | | 143 | 129 | 113 | 385 |
| 1949 | | | | 143 | 104 | | 247 |
| 1950 | | | | 143 | 62 | 51 | 256 |
| 1951 | | 133 | 148 | 143 | 129 | | 553 |
| 1952 | | 138 | 148 | 143 | 129 | | 558 |
| 1953 | | | 23 | 143 | | 113 | 279 |
| 1954 | | | 59 | 143 | | | 202 |
| 1955 | | | | 32 | | | 32 |
| 1956 | | | 148 | 143 | 129 | 113 | 533 |
| 1957 | | | | 143 | 129 | 113 | 385 |

Total divertible during 1928-57 period = 5,000,000 acre-feet
Average " " " " = 165,000 acre-feet

1/ With 2,000 c.f.s. Canal Diverting at St. Anthony. The 2,500 c.f.s. is at the Headworks of the Great Western Canal and 2,400 c.f.s. Assumed Usable Jan.-April, 2,100 c.f.s. in May, and 1,900 c.f.s. in June.

Table 15.--Divertible at Idaho Falls with 2,500 c.f.s. Canal [1/]
Future Conditions

Units: 1,000 acre-feet

| Year | Jan. | Feb. | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| 1928 | | | 1 | 143 | 63 | | 207 |
| 1929 | | | | 9 | | | 9 |
| 1930-42 | | | No | Spills | | | |
| 1943 | | | | 22 | | | 22 |
| 1944 | | | 102 | 75 | | | 177 |
| 1945 | | | | | | | |
| 1946 | | | 73 | 143 | | | 216 |
| 1947 | | | | 143 | | | 143 |
| 1948 | | | | 143 | | | 143 |
| 1949 | | | | 143 | | | 143 |
| 1950 | | | | 143 | | | 143 |
| 1951 | | 133 | 148 | 143 | 61 | | 485 |
| 1952 | | | 9 | 143 | 129 | | 281 |
| 1953-55 | | | | | | | |
| 1956 | | 45 | | 143 | 9 | 15 | 212 |
| 1957 | | | | 143 | 96 | | 239 |

Total divertible during 1928-57 period = 2,400,000 acre-feet
Average " " " " = 80,000 acre-feet

1/ With 2,000 c.f.s. Canal at St. Anthony and Usable Canal Capacity of 2,400 c.f.s. Jan.-April, 2,100 c.f.s. May, and 1,900 c.f.s. June, based on Irrigation Requirements of Great Western Canal.

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Table 16.--Summary of estimated annual diversions available for recharge

Snake Plain Recharge Project, Idaho

| Recharge Area | Condition of Development | | |
|---|---|---|---|
| | Present condition | Present Plus Burns Creek and Teton | Future Conditions |
| | (acre-feet) | (acre-feet) | (acre-feet) |
| St. Anthony Area | 100,000 | 83,000 | 58,000 |
| Idaho Falls Area | 200,000 | 165,000 | 80,000 |
| Idaho Falls-Blackfoot Area | 15,000 | 13,000 | 10,000 |
| TOTAL | 315,000 | 261,000 | 148,000 |

In the above analysis, water was assumed available for recharge diversion only when it was physically passing the recharge diversion point in excess of local use requirements and, as indicated by previous operational studies, water was spilling past Milner Dam. In these operational studies, no attempt was made to distribute spills, through use of inflow forecasts, more or less uniformly over a period of several months. Consequently, spills are often concentrated in one or two months in these studies. The effect of this procedure on flows divertible at St. Anthony would be minor in most years, since divertible flows are often limited by excess flows passing the site. At the Great Western heading, however, it is estimated that average annual divertible flows could be increased by 50 percent, or from 200,000 acre-feet to 300,000 acre-feet, through early season diversions as dictated by inflow forecasts.

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## P L A N   O F   D E V E L O P M E N T

The most suitable and effective recharge sites on the Snake River Plain, determined from this reconnaissance grade investigation, are: (1) The St. Anthony Recharge area, where surplus flows of Henrys Fork could be diverted into the sand and lava area west of St. Anthony; (2) the Idaho Falls Recharge area, where surplus Snake River flows could be diverted to an infiltration area in the lavas west of Idaho Falls; and (3) the Idaho Falls-Blackfoot Gravel Pit Recharge area, where surplus Snake River flows might be diverted into existing gravel pits near the river from Idaho Falls to Blackfoot. Development plans and cost estimates have been prepared for these three recharge possibilities.

Other recharge possibilities investigated to a lesser degree in this study are: (1) The Milner-Gooding Recharge area, where surplus Snake River flows might be carried in the Milner-Gooding Canal to ponding areas that would be located north of Eden and east of Jerome; (2) Big Wood River Recharge area, where surplus flows of the Big Wood River could be diverted into infiltration areas in the lavas downstream from Magic Reservoir; and (3) Little Wood River Recharge area, where surplus Little Wood River flows could be diverted into the lavas lying south of Carey and northeast of Richfield. These latter recharge possibilities involve lesser amounts of water not frequently available. Although they should be included in any catalog of recharge possibilities, it does not appear that the circumstances warrant preparation of plans and estimates for recharge facilities.

### SITE SELECTION

Artificial recharge would cover the widest area and offer the greatest benefit to present and future water use, both underground and surface, if introduced in the northeast or upper portion of Snake Plain. The general direction of movement of ground water in the plain is from northeast to southwest. Figure A, "Contours of the Water Table and Flow Net of the Snake Plain Aquifer," shows the ground-water boundaries, estimated underground flows, and altitude of the ground water in the plain.

The largest areas of existing ground-water pumping are located north and west of Snake River between St. Anthony and American Falls and north of Rupert in and around the Minidoka North Side Pumping Project. Most of the undeveloped arable lands susceptible to ground-water pumping also lie in these general areas.

In the Henrys Fork Basin, the farthest upstream area suitable for ponding lies between the community of Plano and the St. Anthony sand dunes. With the exception of presently irrigated lands in Henrys Fork Valley, this extensive area is a sand and basalt outcrop wasteland. The area can be readily reached by gravity diversions from Henrys Fork, and because of its geographic position, geologic and topographic character, low economic value, and nearness to a major surface-water source, the St. Anthony Recharge area is one of considerable recharge potential. Recharge water in this area would contribute to stabilization of ground-water levels in the Mud Lake region. However, the flowlines from this area pass north of points of major use farther down the plain to emerge in the Thousand Springs area. Much of the basalt in this recharge area is covered by a blanket of windblown sand and silt that partially clogs the openings in the basalt and would reduce infiltration capacity. At this same time, this blanket acts as a natural filter, removing sediments and other undesirable matter from the water before it reaches the regional ground water. It is believed that this area, with water spreading, is well adapted for use as a recharge area.

An investigation of diversion possibilities in the Idaho Falls area was made from the confluence of Henrys Fork and Snake River downstream to a point a few miles below Idaho Falls. One possibility considered was the diversion of surplus flows below the confluence of the two streams near Menan Buttes at an elevation of about 4800 feet. Diversion at this point would require a canal about 60 miles long traversing presently cultivated lands most of the way. This canal would discharge into the lava fields southwest of Idaho Falls. Another possibility examined was a diversion nearer Roberts, Idaho. This canal would traverse the area just slightly above the existing Great Western Canal alignment, would be located in a difficult terrain for construction purposes, and would discharge into the lava fields southwest of Idaho Falls. The main contours through this area are shown on Drawing No. 932-125-18. Diversions below Idaho Falls could be made, but sites in the lavas available for ponding are scattered and limited. Most of the lands to be crossed before reaching exposed lavas are irrigated, thus adding rights-of-way complications.

It was concluded from the investigation of diversion possibilities immediately below the mouth of Henrys Fork that the most favorable diversion at the highest elevation of Snake River would be at a point on Snake River about 9 miles upstream from Idaho Falls. A 2,500 cubic foot per second canal would extend from the point of diversion to an area about 8 miles southwest of Idaho Falls, where the flow would enter ponding areas located in the lavas. The infiltration area is mostly raw, broken basalts. However, there are several areas covered with fine, wind-deposited sediments that occur as depressions surrounded or bordered by the interrelated basalt flows. These depressions form the sites for ponding areas.

## FACILITIES

### St. Anthony Recharge Area

The St. Anthony Recharge area is in Fremont and Madison Counties, Idaho, near the town of St. Anthony at the eastern boundary of the

Snake River Plain. Water for recharge would be diverted from Henrys Fork.

Facilities of the St. Anthony Recharge area include St. Anthony Headworks and Recharge Canal, Egin Lakes Enlargement, and four other ponding areas. The 2,000 cubic foot per second capacity Recharge Canal would head in Henrys Fork about three miles upstream from St. Anthony and would carry surplus flows to serve ponding areas. Facilities and their locations are shown on Drawing No. 932-125-19.

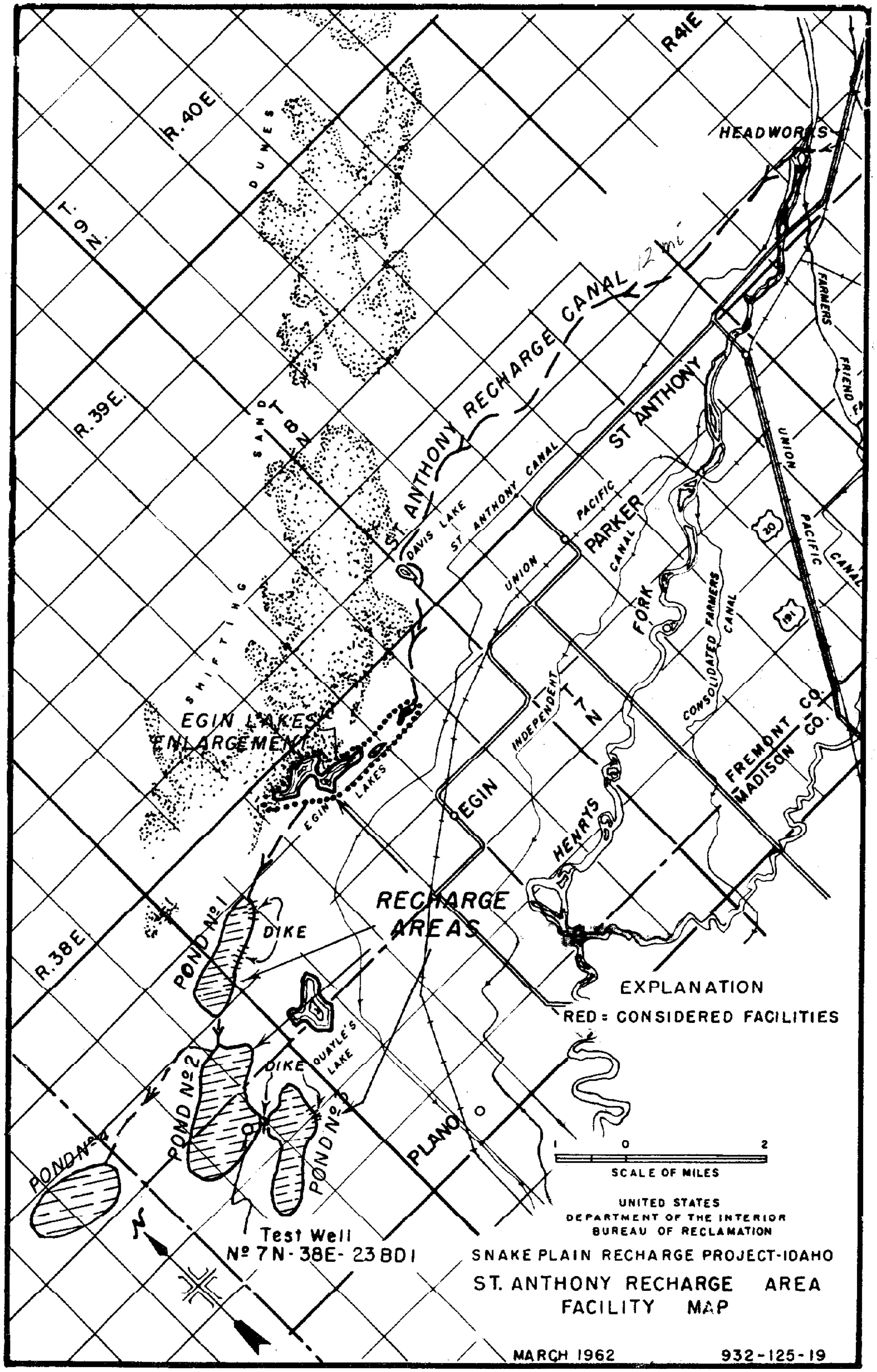
St. Anthony Headworks and Recharge Canal

The headworks structure of the St. Anthony Recharge Canal would be adjacent to an existing diversion structure across Henrys Fork. This existing structure now diverts flows to the Farmers Friend Canal on the south bank of the river and to the St. Anthony Canal on the north bank. Also, it is considered adequate for diversions to the Recharge Canal. Control of flows at the headworks structure would be by motor-operated radial gates. A fish-screen structure with rotary-type screens would be in the Recharge Canal about 150 feet downstream from the headworks structure. Fish would be conveyed back to Henrys Fork from the fish-screen structure through a bypass pipe with outlet in the river below the diversion structure. Design of the headworks and fish-screen structures are shown on Drawing No. 932-D-1.

The Fish and Wildlife Service recommends that fish-passage facilities be provided on both ends of the existing diversion structure, and concrete fish ladders have been included in the cost estimate to provide for such passage.

From the headworks structure, the 2,000 cubic foot per second Recharge Canal would run westerly to the existing Egin Lakes and from there southwesterly to the first of the ponding areas. The canal would cross a small amount of presently irrigated land, but is generally located in nonirrigated pasture or wasteland. Major structures include county road bridges, concrete control drops, and concrete pipe siphons for crossing existing irrigation waterways.

Design and construction of the Recharge Canal would recognize its unconventional purpose. Crossings of draws that extend away from farmland into unused wasteland could be made by a single dike allowing water to spread into the draws. Where the canal is cut through rock, excavation methods should be adopted to produce a maximum amount of shattering of the canal base and sides. By these and perhaps other techniques, the maximum conveyance loss can be achieved. This would keep ponding areas at the end of the canal to a minimum and aid Egin Bench farmers in producing desired subirrigation water levels in the spring.


R.40E.
R41E
HEADWORKS
T.9N.
R.39E.
ST ANTHONY RECHARGE CANAL
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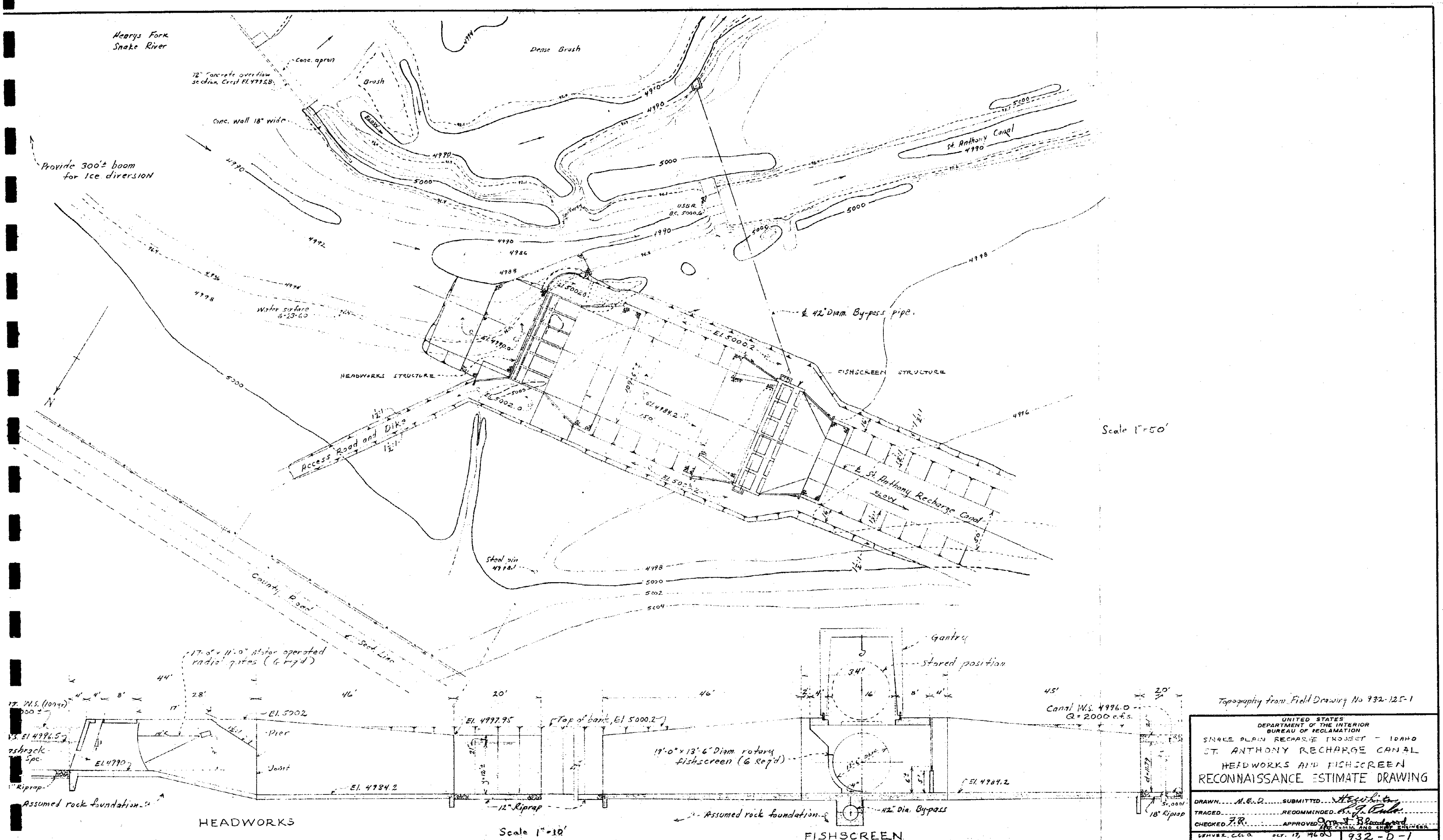
FARMERS FRIEND
ST ANTHONY
UNION PACIFIC
PARKER CANAL
ST ANTHONY CANAL
DAVIS LAKE
SHIFTING SAND DUNES
T.8N.
FORK
CONSOLIDATED FARMERS CANAL
T.7N.
INDEPENDENT
EGIN LAKES ENLARGEMENT
EGIN LAKES
EGIN
HENRYS
FREMONT CO.
MADISON CO.
RECHARGE AREAS
DIKE
POND No 1
R.38E.
QUAYLE'S LAKE
POND No 2
POND No 3
POND No 4
PLANO
EXPLANATION
RED = CONSIDERED FACILITIES
1 0 2
SCALE OF MILES
Test Well
No 7N-38E-23BD1
N
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SNAKE PLAIN RECHARGE PROJECT-IDAHO
ST. ANTHONY RECHARGE AREA
FACILITY MAP
MARCH 1962
932-125-19



Henrys Fork Snake River
Provide 300'± boom for ice diversion
12" Concrete overflow section, Crest El. 4995.8
Conc. apron
Conc. wall 18" wide
Brush
Dense Brush
Water surface 6-23-60
HEADWORKS STRUCTURE
Access Road and Dike
County Road
Seed Line
FISHSCREEN STRUCTURE
℄ 42" Diam. By-pass pipe
℄ St. Anthony Recharge Canal
St. Anthony Canal
Steel pin 4978.1
Scale 1"=50'
17.0' x 11.0" Motor operated radial gates (6 req'd)
El. 5002
Pier
Joint
El. 4990
El. 4984.2
El. 4997.95
Top of bank, El. 5000.2
12" Riprap
Assumed rock foundation
HEADWORKS
Scale 1"=10'
19'-0" x 13'-6" Diam. rotary fishscreen (6 Req'd)
Gantry
Stored position
42" Dia. By-pass
FISHSCREEN
Canal W.S. 4996.0
Q = 2000 c.f.s.
18" Riprap
Topography from Field Drawing No. 932-125-1
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SNAKE PLAIN RECHARGE PROJECT - IDAHO
ST. ANTHONY RECHARGE CANAL
HEADWORKS AND FISHSCREEN
RECONNAISSANCE ESTIMATE DRAWING
DRAWN M.E.D.
TRACED
CHECKED F.R.
DENVER, COLO. OCT. 17, 1960
932-D-1

## Plan of Development

### Egin Lakes Enlargement

The existing Egin Lakes consist of three small ponding areas lying along the sand dunes west of St. Anthony. They were formed when local irrigators constructed low dikes to create ponds to raise the ground-water levels for subirrigation. A larger and longer dike would be constructed along the south and west boundaries of the existing lake area. This new dike would have a maximum height of about 16 feet and would be approximately 8,400 feet long. It would form one large lake having a capacity of about 2,200 acre-feet. Some of the water brought into this lake by the Recharge Canal would pass from the lake to the lower reach of the Recharge Canal by means of a concrete overflow spillway located at the western end of the dike. This larger Egin Lake would serve the subirrigation functions of the existing lakes and would add surplus Henrys Fork water into the regional ground water as artificial recharge. About 328 acres of dry pasture land above the present pond levels would be needed for the enlarged Egin Lakes.

### Ponding Areas

Natural desert terrain, about 10 miles west of St. Anthony, is composed of lavas overlain with sand in depths varying from a few inches to several feet. The St. Anthony Recharge Canal would discharge into ponding areas located in this area. For the purposes of this investigation, four ponds with a total capacity of over 40,000 acre-feet have been included in the plan for development. These ponds are located in depressions in the terrain, and would be formed by constructing small earth dikes and interconnecting channels as required. The general ground slope is to the west, and there is an almost unlimited wasteland area with numerous depressions in the general vicinity. Operating experience probably will be needed to define the exact ponding area and capacity.

Pond No. 1 would have a capacity of about 1,350 acre-feet and a surface area of approximately 295 acres. The pond would be formed by two dikes having a total length of about 950 feet. The maximum height of these dikes would be about 10 feet, with an average height of about 5 feet. Pond No. 2, located southwest of Pond No. 1, would have a capacity of about 6,300 acre-feet, with a surface area of approximately 670 acres. One dike, about 2,600 feet long with a maximum height of approximately 11 feet, would be required to form this ponding area. Pond No. 3, located south of No. 2, would have a capacity of 3,200 acre-feet and a surface area of 430 acres. This pond would be formed by constructing a 1,700-foot dike, with a maximum height of 6 feet, along the eastern edge of the pond. Pond No. 4 would be connected to the northern edge of Pond No. 2 by a 6,500-foot channel and would consist of a series of natural depressions in what appears from fragmentary data to be a wide westward sloping topographic trough extending west 10 or 12 miles toward Hamer. Topographic coverage for this area is not available, but a visual inspection has been made and spot elevations extended to a few wells in the general area. It is estimated that a capacity of 30,000 to 40,000 acre-feet is readily available without construction of dikes or channels or threatening any presently cultivated lands.

Recharge Testing

The U. S. Geological Survey maintains water-level studies and has the logs of wells drilled in southeastern Idaho. From their studies and information, it appears that the intermediate soil layers in the general area of the St. Anthony Recharge site are large lenses of varying thickness that interfinger with the lava flows. The seepage rates through the soil layers are lower than the seepage rate through the basalt.

Test Well No. 7N-38E-23BD1, located west of St. Anthony near the southern edge of Pond No. 2, was drilled in 1958. The log for this well is as follows: Sand, 5 feet; basalt, 35 feet; silty sand with some gravel, 120 feet; basalt, 66 feet; and clay and silt in the bottom. The basalt layers are fractured, jointed, and highly permeable. The ground-water level was about 40 feet below the ground surface when the well was drilled. When tested, this 16-inch diameter well produced about 1,300 gallons per minute for 17 hours, with a drawdown of 2½ feet. The U. S. Geological Survey maintained a record of the depth of the water in Test Well No. 7N-38E-23BD1 from its completion in 1958 until the infiltration tests in 1961. Fluctuations of the water level were only a few feet during that time.

In 1961, a 30-day recharge test was conducted adjacent to this well by pumping 2,500 gallons per minute continuously into a ponding area having a capacity of about 260 acre-feet. With a total amount of about 300 acre-feet being pumped during the test, the pond never reached a total volume exceeding 100 acre-feet.

In 1961, small observation wells were drilled adjacent to Egin Lakes to observe the slope of the mound of infiltrating water. The surface area of the larger lakes was obtained at two different intervals by photogrammetric methods. During the period when surplus flows were being diverted to the lakes, the quantities of water were measured.

During the recharge testing in 1961, in cooperation with the U. S. Geological Survey, infiltration tests were run on samples of the soil mantle from auger holes near Egin Lakes and Auger holes in the ponding area near Test Well No. 7N-38E-23BD1. Permeability rates were found to be almost identical for the two areas. From the 1961 recharge testing at both Egin Lakes and Well No. 7N-38E-23BD1, it was determined that the seepage rates for the St. Anthony ponding area would run in the order of 0.3 acre-foot per acre per day. The seepage rates of the basalt layers would be several times this order, and it is known that portions of the ponding areas are bare, broken lava with no soil mantle. Assuming an average seepage rate of about 0.5 acre-feet per acre per day for the 8,000 acres in the proposed St. Anthony ponding areas, including the enlarged Egin Lakes, a total of about 4,000 acre-feet per day of water could infiltrate into the ground-water table. The proposed diversion of 2,000 cubic feet per second, or about 4,000 acre-feet per day, could be contained within the ponding area studied.

In the 1961 U. S. Geological Survey report on recharge testing, a method of drainage well construction is advanced. It would be particularly applicable in instances where two highly permeable basalt layers exist that are separated by sediment layers of low permeability. This method proposed to drill through soil and the upper permeable layers and into the lower permeable layer. This hole would be tightly cased in the soil and the sedimentary interbed and capped and sealed at the ground surface. The upper permeable layer would be open, or the casing would be perforated through a portion of the layer, probably just above the sedimentary interbed. In this fashion, the upper permeable layer could be drained into the lower permeable layer after a clarifying filtration through the ground surface and a portion of the upper permeable layer. It is estimated that a 20-inch hole with a 10-foot head could drain as much as 10 cubic feet per second of filtered water into the highly permeable basalts that contain and move the regional ground water.

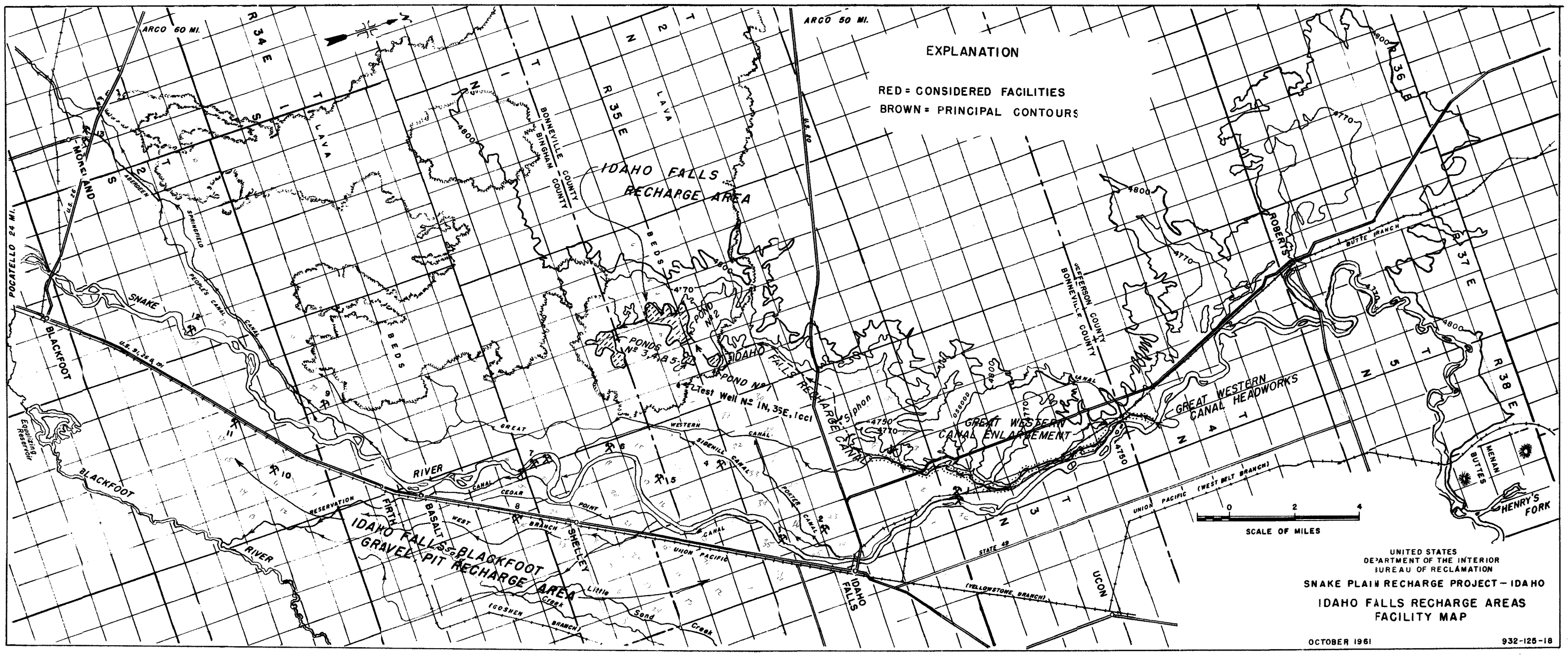
## Idaho Falls Recharge Area

The Idaho Falls Recharge area lies along Snake River west of Idaho Falls in Jefferson, Bonneville, and Bingham Counties, Idaho.

Facilities included in the plan of development for the Idaho Falls Recharge area are shown on Drawing No. 932-125-18.

### Great Western Headworks and Canal Enlargement

The existing Great Western Canal diverts from the Snake River about one-third mile upstream from a small dam built to divert water to the Idaho Canal. From its point of diversion, the Great Western Canal runs southwesterly to about 6 miles northeast of Blackfoot, serving a large area lying on the west side of Snake River. This existing canal has a capacity of about 700 cubic feet per second at the point of diversion. The first 10.9 miles of this canal would be enlarged to a capacity of 2,500 cubic feet per second to carry recharge water.



EXPLANATION
RED = CONSIDERED FACILITIES
BROWN = PRINCIPAL CONTOURS
IDAHO FALLS RECHARGE AREA
IDAHO FALLS - BLACKFOOT GRAVEL PIT RECHARGE AREA
GREAT WESTERN CANAL ENLARGEMENT
GREAT WESTERN CANAL HEADWORKS
PONDS Nº 3, 4, & 5
POND Nº 1
Test Well Nº 1N, 35E, 1cc1
Siphon
IDAHO FALLS
BLACKFOOT
SHELLEY
FIRTH
BASALT
MORELAND
ROBERTS
UCON
MENAN BUTTES
HENRY'S FORK
SNAKE RIVER
BLACKFOOT RIVER
ARCO 60 MI.
ARCO 50 MI.
POCATELLO 24 MI.
BONNEVILLE COUNTY
BINGHAM COUNTY
JEFFERSON COUNTY
LAVA BEDS
R 34 E
R 35 E
R 36 E
R 37 E
R 38 E
T 1 N
T 2 N
T 3 N
T 4 N
T 5 N
T 1 S
T 2 S
UNION PACIFIC
STATE 48
4800
4770
4750
SCALE OF MILES
0
2
4
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SNAKE PLAIN RECHARGE PROJECT – IDAHO
IDAHO FALLS RECHARGE AREAS
FACILITY MAP
OCTOBER 1961
932-125-18

A new headworks structure would be constructed at the point of diversion. This structure would be located along the existing canal alignment a few feet downstream from the existing headworks. Diversion control would be with radial gates. A fish-screen structure with rotary screens and a bypass conduit to carry fish back into the Snake River would be constructed about 200 feet downstream from the headworks structure. Details of the headworks and fish-screen structures are shown on Drawing No. 932-100-1. The Fish and Wildlife Service recommends that fish passage facilities be constructed over the existing diversion dam. Concrete fish ladders over both ends of the dam have been provided for in the cost estimate.

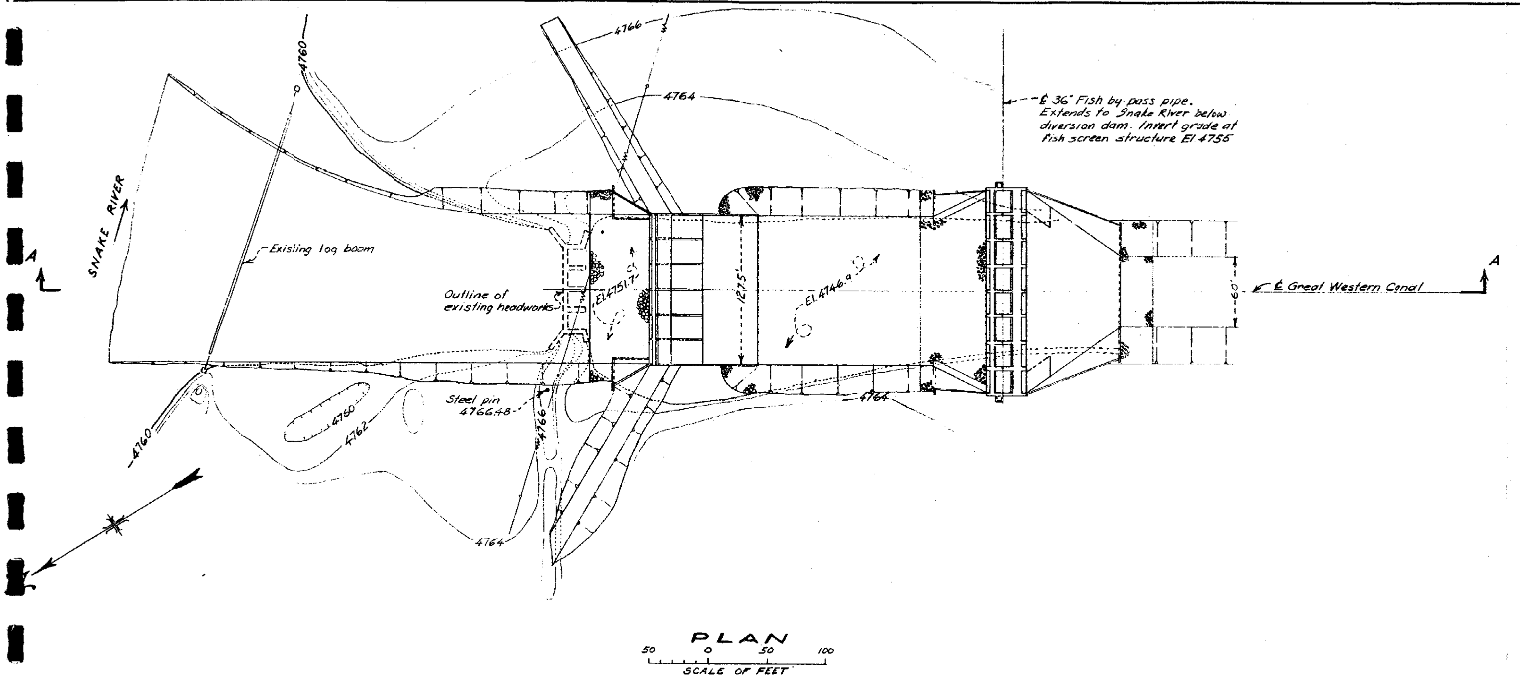
Enlargement of the existing Great Western Canal would consist of deepening and widening on the uphill side of the canal. Turnouts to all existing laterals are provided for, as are checks to maintain the existing water surface where required. The enlarged canal would have a rolled earth lining through the portion running in lava (3.8 miles). The purpose of this lining is to assure that water losses in the enlarged canal would not be greater than are now occurring and that local seeped areas or drainage problems would not be created or aggravated by the canal enlargement.

## Idaho Falls Recharge Canal

This 2,500 cubic foot per second canal would be constructed from a point on the Great Western Canal near Oakland Valley southwesterly for approximately 7 miles to an area of rough, exposed basalt. This canal would have a base width of about 60 feet and, at full capacity, would have a depth of approximately 11 feet. Lining is not included for this canal. Major structures include a concrete siphon 1,500 feet long across Oakland Valley and bridges at county road and highway crossings. Much of the area traversed by this canal is under irrigation from privately developed wells, and acquisition of right-of-way through these lands would be required.

## Ponding Area

The Recharge Canal would discharge into an area consisting largely of rough, exposed basalt southwest of Idaho Falls. These basalts are very broken and irregular with deep fissures and little, if any, soil cover. Natural depressions in this area would be utilized for ponding, as necessary. Construction to develop these ponding areas would be minor, consisting of a few small dikes and channels cut through the lavas to carry water from one depression to another. Recharge ponds thus formed in the particular lava area would have a combined capacity of about 10,000 acre-feet.

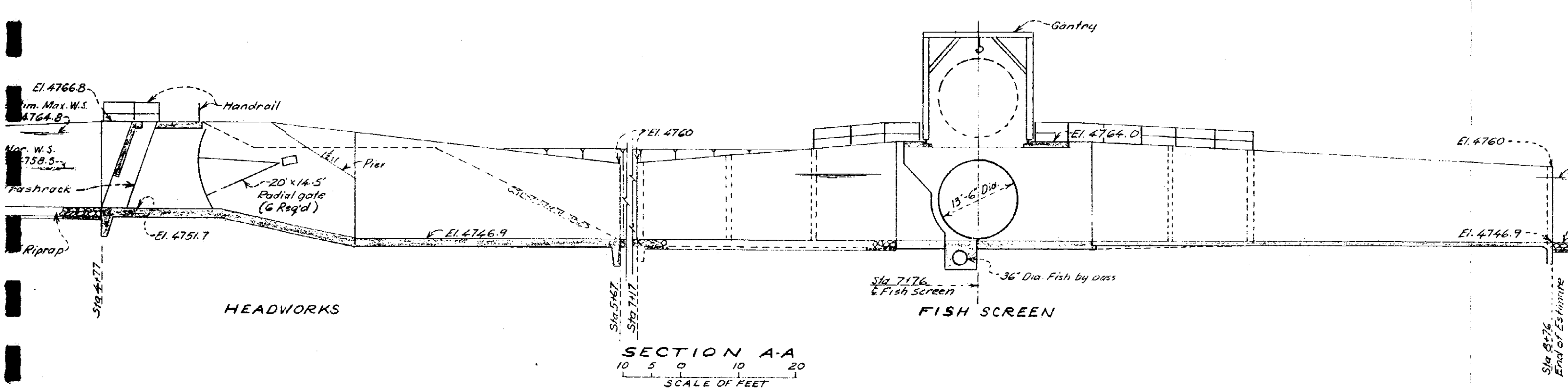



## NOTES

Great Western Canal will be enlarged to a capacity of 2500 cfs. to serve both irrigation and Snake Plain Recharge purposes. When recharge water is not available, the existing water surface will be maintained to serve irrigation requirements.

Check and wasteway at Mile 1.1

Pumping plant at Mile 0.6




UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
SNAKE PLAIN RECHARGE PROJECT-IDAHO

# GREAT WESTERN CANAL
# HEADWORKS AND FISH SCREEN

RECONNAISSANCE ESTIMATE

| | | | |
|---|---|---|---|
| DRAWN | LKS | SUBMITTED | E. Fouisner |
| TRACED | | RECOMMENDED | Frank G. Mueller |
| CHECKED | E.K. | APPROVED | R. H. Harris |
| Boise, Ida. May 17, 1961 | | 932-100-1 | |

Recharge Testing

Test Well No. 1N-36E-1CC1 was drilled in 1958 to a depth of 218 feet in the lavas southeast of the ponding sites. This well was used in 1961 as a source of water for two recharge tests. The log for this test well shows the following thicknesses of strata from top to bottom: basalt, 36 feet; sandy silt, 16 feet; clay, silt, and sand, 20 feet; basalt, 22 feet; sandy silt, 8 feet; and basalt, 92 feet. All of the basalt layers are fractured, jointed, and highly permeable. The ground-water level was approximately 145 feet below the ground surface when the well was drilled. When this 16-inch diameter well was tested it yielded about 2,000 gallons per minute for 9 hours with a drawdown of $1\frac{1}{2}$ feet. For the recharge test in 1961, about 2,500 gallons per minute were pumped from this well for 30 days to a small depression in the lavas adjacent to the well. All of the pumped water immediately disappeared into the fissures of the lavas, and no ponding occurred. About 350 acre-feet were thus discharged into the lavas. Several small diameter holes were drilled at varying distances from the point where the test water entered the lavas. Water-level observations in these holes established the slope of the mound of water developed by the test. Detailed results of the tests are contained in the attached report of the Geological Survey.

Firm quantitative conclusions cannot be drawn from the Geological Survey test. Indications are that the maximum possible permeability coefficient of the upper basalt is on the order of 87,000 gallons per day per square foot. The rate of seepage through the silt is not clearly established but the maximum possible is 0.8 foot per square foot per day and the actual rate was probably considerably less. Laboratory permeability tests on these silts gave maximum permeability rates of 0.27 foot per square foot per day and averaged about 0.1 foot per square foot per day.

Thus, while large quantities of water can be added to the Snake River aquifer by recharging through the basalts, silt layers above the water table inhibit downward movement of the water. The degree of adverse influence of these layers depends upon their thickness, attitude, extent, and local permeability. Generally, the silts interfinger with the basalts and vary considerably in extent and thickness from place to place. Scanty evidence indicates that the silts found in the area of the recharge well may not be present in the area of the proposed recharge ponds.

The practical area for artificial recharge in the jagged, bare basalts west of Idaho Falls is about 900 acres, and this amount of ponding area has been adopted for this analysis and report. Almost all of this acreage is covered with broken basalts on the surface that would readily accept the recharge water contemplated for delivery. The critical factor is the extent of any fine-grained sediments intermediate between the surface lavas and the regional ground water.

The evidence to date concerning the Idaho Falls area shows the area to have promising physical characteristics for artificial recharge, provided extensive underlying sediments are not present beneath the ponding areas above the regional ground-water level. The log of the test well a few miles southeast shows underlying sediments, while an irrigation well about the same distance northwest shows no underlying sediments. Consequently, a final physical suitability determination must be based on thorough explorations beyond the scope of this report.

## Idaho Falls-Blackfoot Gravel Pit Recharge Area

Recharge in the area along Snake River between Idaho Falls and Blackfoot would utilize surplus floodflows by diversion to existing gravel pits. These gravel pits are contributory to the regional ground water as evidenced by the fact that some pits immediately adjacent to the river are dry, even though their bottom elevations are as much as 5 feet below the river water surface. The exact slope of the ground water infiltrating from the riverbed has not been definitely determined, but it is estimated by the U. S. Geological Survey that the slope is fairly steep and away from the riverbed. Most of the river in this reach is perched as much as 50 feet above the regional water table. In general, it is a losing stream. Well logs on both sides of the river show deposits of gravel to depths of 50 to 100 feet below the streambed. Basalt ridges are scattered throughout the length of the streambed.

All available hydrologic, geologic, and ground-water evidence points to the conclusion that ground water in this area is contributing inflow to American Falls Reservoir. Surplus floodflows diverted to these gravel pits would relate directly to American Falls Reservoir inflows from ground water. In addition, this diversion would contribute to ground-water supplies for the considerable amount of pumping being done west of Snake River between Idaho Falls and American Falls.

No tests were performed to determine the rate of seepage from the gravel pit areas. However, literature on recharge pits such as the one tested in Peoria, Illinois, indicates some rates running as high as 200 acre-feet per day per acre recharging into a gravel strata, and as low as 1.5 acre-feet per day per acre when the filter was badly silted. A recharge water-clarifying medium is not suggested for the gravel pit recharge operation in this area, nor does yearly cleaning of the pits appear practical. Most of the pits are located on the bench above the river and their bottoms are probably more than 50 feet above the water table. An average seepage rate of about 2 acre-feet per day per acre, about one-half that used in the Idaho Falls Recharge area, should be a conservative estimate for the gravel pits. This figure, applied to the 280 total acreage of the pits, would infiltrate a total of 560 acre-feet per day.

Thirteen gravel pits are included in this study with a total capacity of about 2,900 acre-feet. Four of these pits, with a total capacity of about 450 acre-feet, lie east of Snake River and vary in distance from the river from $1\frac{1}{2}$ miles to immediately adjacent. The nine other pits lie west of Snake River at distances from the river ranging from $4\frac{1}{2}$ miles to 0.1 mile. Existing canals in the area pass close to all of the pits and could be utilized. A total of about 6 miles of canal, ranging in capacity from 2 to 25 cubic feet per second, is the only facility required for diversion to the gravel pits.

The relative locations of these gravel pits are shown on Drawing No. 932-125-18.

## Other Recharge Area Possibilities

There are several potential areas for recharge to Snake Plain ground water other than the three sites presented. Three such areas are the Milner-Gooding Recharge area, the Big Wood River Recharge area, and the Little Wood River Recharge area. A detailed study of these areas was not undertaken, but a general description of each has been included as a matter of information on recharge possibilities in the area studied.

### Milner-Gooding Recharge Area

The Milner-Gooding Canal diverts from the Snake River at Milner Dam, runs southwesterly past Shoshone, and ends just north of Gooding. The first 30 miles of this canal has a capacity of about 1,300 cubic feet per second. This reach of the canal runs through a large wasteland area that is mostly lava overlain with a shallow mantle of soil. During the construction of this canal, numerous turnout structures were included. Many of these turnouts are seldom utilized at the present time. By constructing dikes in depressions that exist in the area, ponding areas would be created that could be filled with Snake River surplus flows during the nonirrigation season or when the full capacity of the canal was not required. The ground-water supply in the Jerome-Wendell area would be recharged by these ponding areas.

Water studies indicate that with no diversions upstream from Milner for recharge, an average of about 70,000 acre-feet could be delivered to infiltration fields through the existing Milner-Gooding Canal. However, these infiltration fields are too close to a positive boundary of the Snake Plain aquifer to accomplish appreciable increases in the long-term holdover storage in the main aquifer.

## Plan of Development

### Big Wood River Recharge Area

Downstream from Magic Reservoir and north of Shoshone, there is a large wasteland area mainly underlain with lava where surplus Big Wood River waters could be released to recharge the ground water in this area. Facilities required for this recharge area probably would include a diversion structure on the Big Wood River, canals to transport the water into the lavas and wastelands, and dikes to form ponds where the water would dissipate into the underlying ground water. A detailed study of facilities to transport surplus waters to points of dispersal in this area was not developed in this reconnaissance, because water studies show that water would be divertible from the Big Wood River only 3 percent of the time without reducing power production at Idaho Power Company's Upper and Lower Malad Powerplants.

### Little Wood River Recharge Area

Downstream from the confluence of Silver Creek and Little Wood River, there is a large lava and wasteland area where surplus Little Wood River flows could be diverted for recharge of the ground water in the area. Facilities to effect this diversion would consist of diversion structures, canals, and dikes to form ponding areas. A detailed plan of development for the Little Wood River Recharge area was not undertaken, because water studies show that water would be divertible from the Little Wood River only 3 percent of the time without reducing power production at Idaho Power Company's Upper and Lower Malad Powerplants.

## PROJECT COSTS

The costs of the proposed development would consist of the construction costs and the annual costs of operation and maintenance.

### Construction Cost

Estimated construction costs for the facilities for which a specific analysis was made amount to $4,640,000 for the St. Anthony Recharge area, $8,380,000 for the Idaho Falls Recharge area, and $130,000 for the Idaho Falls-Blackfoot Gravel Pit Recharge area, making a total of $13,150,000 at April 1961 price levels if all areas are combined.

The total estimate includes $430,000 at the St. Anthony Recharge area and $625,000 at the Idaho Falls Recharge area for the mitigation and preservation of the existing fishery. The Official Estimate, Form PF-1, following page 46, gives these costs by features.

## Annual Costs

Annual costs include expenses for annual operation and maintenance. All replacements are included in normal maintenance for all property items. It has been presumed that operation and maintenance of the three areas would be carried out under the existing operating office serving constructed storage and other project works in the Upper Snake Basin.

Annual costs of operation and maintenance are:

| | |
|---|---|
| St. Anthony Recharge area | $ 7,500 1/ |
| Idaho Falls Recharge area | 12,500 1/ |
| Idaho Falls-Blackfoot Gravel Pit Recharge area | 1,000 |
| Total | $21,000 |

1/ Includes $500 for fish and wildlife facilities.

PF-1
(6-57)
Bureau of Reclamation

OFFICIAL
ESTIMATE

Project: SNAKE PLAIN RECHARGE PROJECT, WASHINGTON

Date of Estimate: FEBRUARY 1962

Prepared by: ______________ Approved by: ______________

(Prices as of April 1961)

Sheet ____ of ____

| Cost Classification (1) | DESCRIPTION (2) | Quantity (3) | Unit Cost (4) | Total Estimate (5) | Labor and materials by contractor (6) | Materials and Equipment by Gevt. (7) | Labor by Government Forces (8) | Service Facilities (9) | Investigations, Engineering and Other Costs (10) | Previous Official Estimate (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| | ST. ANTHONY RECHARGE AREA | | | | | | | | | |
| 02.01 | ST. ANTHONY RECHARGE CANAL HEADWORKS | 2,000 | c.f.s. | 1/ 400,000 | 305,000 | | | 3,000 | 92,000 | |
| 05.01 | ST. ANTHONY RECHARGE CANAL | 2,000 | c.f.s. | 2/ 2,350,000 | 1,885,000 | | | 19,000 | 446,000 | |
| 09.01 | CHANNELS, LEVEES, AND FLOODWORKS | 43,500 | A.F. | 1,845,000 | 1,490,000 | | | 15,000 | 340,000 | |
| 15.01 | GENERAL PROPERTY | | | 45,000 | 36,000 | | | | 9,000 | |
| | Subtotal Construction Cost | | | 4,640,000 | | | | | | |
| | IDAHO FALLS RECHARGE AREA | | | | | | | | | |
| 02.02 | GREAT WESTERN CANAL HEADWORKS | 2,500 | c.f.s. | 460,000 | 352,000 | | | 4,000 | 104,000 | |
| 05.02 | GREAT WESTERN CANAL ENLARGEMENT | 2,500 | c.f.s. | 3/ 3,710,000 | 2,961,000 | | | 30,000 | 719,000 | |
| 05.03 | IDAHO FALLS RECHARGE CANAL | 2,500 | c.f.s. | 3,385,000 | 2,700,000 | | | 28,000 | 657,000 | |
| 09.02 | CHANNELS, LEVEES, AND FLOODWORKS | 10,000 | A.F. | 745,000 | 597,000 | | | 6,000 | 142,000 | |
| 15.02 | GENERAL PROPERTY | | | 80,000 | 64,000 | | | 1,000 | 15,000 | |
| | Subtotal Construction Cost | | | 8,380,000 | | | | | | |
| | IDAHO FALLS-BLACKFOOT GRAVEL PIT RECHARGE AREA | | | | | | | | | |
| 09.03 | CHANNELS, LEVEES, AND FLOODWORKS | 2,900 | A.F. | 125,000 | 100,000 | | | 1,000 | 24,000 | |
| 15.03 | GENERAL PROPERTY | | | 5,000 | 4,000 | | | | 1,000 | |
| | Subtotal Construction Cost | | | 130,000 | | | | | | |
| | TOTAL CONSTRUCTION COST | | | 13,150,000 | | | | | | |
| | TOTAL PROJECT COST | | | 13,150,000 | | | | | | |

1/ Includes $5,000 for fish ladder over existing diversion dam
2/ Includes $425,000 for fish screens on canal diversion headworks
3/ Includes $625,000 " " " " " " and fish ladders over existing diversion dam

# PROJECT FUNCTIONS AND ACCOMPLISHMENTS

Recharge of the Snake Plain aquifer would favorably affect the water supply of almost all of the potentially irrigable lands in the Snake River Basin above Bliss. In addition, it would benefit in varying degree the lands now irrigated from the ground water of the Snake Plain aquifer and surface-water irrigated lands in this area. Artificial recharge also would serve as a measure of flood control by putting water from peak flows underground, materially contribute to power production by reducing peak flows and augmenting ground-water discharge into Snake River, and be beneficial to municipal and industrial supplies downgradient from points of recharge.

## IRRIGATION

There are approximately 2,365,000 acres of irrigated land in Snake River Basin above Bliss. Of this total, about 615,000 acres are irrigated from ground water pumping and 1,750,000 from surface water. About 860,000 acres of this land would require a supplemental water supply. In addition, there are an estimated 580,000 acres of potentially irrigable dry land that need a full water supply.

Recharge would increase the flows of springs above Milner that are contributory to Snake River. These additional inflows to Snake River, within limitations of available storage during the period of increased flows and the requirement for additional water, could be used as supplemental irrigation water for lands that are irrigated from the Snake River above Bliss. In addition, water pumped from the aquifer into Snake River above Milner Dam, or into a distribution system at any point, could be used through system operation as supplemental irrigation water for practically all of the presently irrigated land above Bliss. The stabilizing effect of recharge on the water table in the areas where such exchange pumping might develop would represent a benefit.

Within the area underlain by the Snake Plain aquifer proper, there are about 920,000 acres of presently irrigated land, of which 420,000 acres are irrigated with ground water and 500,000 acres with surface water. Many operators supplement their surface supply with ground water. Irrigators who pump all or part of their water from wells would realize a reduction in pumping costs by virtue of the reduced pump lift that would be associated with recharge. This would also be true for the estimated 250,000 acres of arable land that are expected to be developed in the near future. At the present time, these lands are being brought under irrigation at the rate of from 20,000 to 25,000 acres a year. As these lands are developed, they would benefit by reduced pump lift.

## Project Functions and Accomplishments

In the Upper Snake River Basin study, completed in 1961, more than 275,000 acres of arable land were identified that could be irrigated by making a coordinated use of idle components of ground water and surface water. Development of a source of water to supplement the inadequate supply now available for a number of these major areas is closely associated with the recharge plan. The most promising source of new water in dry years for the Salmon Falls Project, for example, is the unused ground water in the Snake River Plain. Ground water could be delivered to the Snake River system (above Milner) to replace surface water diverted from Snake River to the Salmon Falls area. The cost of pumping this water, which is a major factor in determining the economic feasibility of such a project, would be reduced by any reduction in pump lift that would accompany the recharge plan.

In the nontributary valleys north of the Snake River Plain, additional withdrawals of surface or ground water to supplement the water supply for presently irrigated lands, or to irrigate new lands, would reduce the amount of natural recharge to the Snake Plain aquifer. This reduction of natural recharge could be partially offset by artificial recharge. There are about 120,000 acres of irrigated land needing supplemental water, most of which is in the Big Lost River Valley, and about 500,000 acres of arable land in all the nontributary areas excluding Mud Lake, the development of which would affect the Snake Plain aquifer in this manner.

Development of new lands and supplying supplemental water to presently irrigated lands in the Snake River Basin above Bliss through ground-water pumping, exchange of water, and system operation are largely dependent upon utilizing the Snake Plain aquifer as a source of water. Recharge of this aquifer with surplus surface flows is a logical extension of the employment of unused water resources.

Benefits from recharge of the Snake Plain aquifer associated with irrigation from both ground- and surface-water sources, flood control, and power are directly influenced by the direction, rate of movement, and elevation of ground water. A general summary of expected effects of artificial recharge follows to relate physical responses from recharge and estimated amount of monetary benefits.

The effect of irrigation percolation on ground-water levels has been observed in water wells. Initially, the percolating water forms a steep-sided mound in the water table. The weight of the additional water causes the base of the mound to spread laterally in all directions so that in time the water table rise is widespread; but the amount of rise is progressively less with increasing distance from the source.

Since the ever widening rise in water table is due more to pressure transfer than water movement the mound spreads laterally faster than the water moves. Application of water from Aberdeen-Springfield Canal is reflected almost immediately in nearby wells but the time lag between application of water and rising water levels becomes progressively greater as distance from the source increases. It requires about 80 days for the effect of recharge from the Aberdeen-Springfield Canal to be reflected in wells at Atomic City, 22 miles away. Isotope tracers indicate that physical movement of water here is about 10 to 50 feet per day.

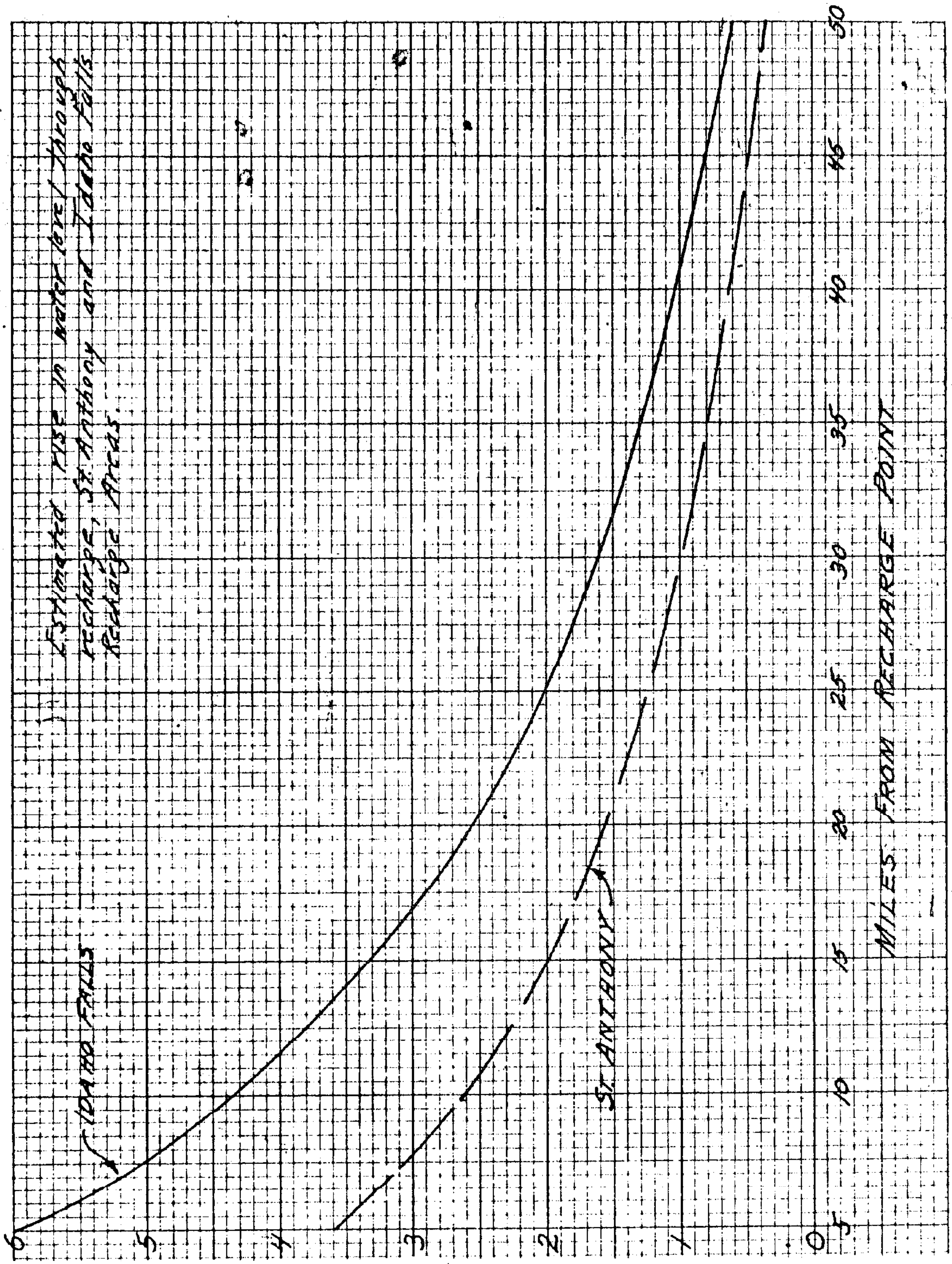
Surface water diverted from Henrys Fork to an infiltration field west of St. Anthony would percolate downward and form a mound in the water table. This mound would spread in all directions but with decreasing effect as distance from the recharge area increased as shown in Figure B. The recharge cone would not be completely symmetrical; it would be distorted by variations in permeability of the aquifer, impermeable barriers or boundaries, and by the initial slope of the water table.

The Snake Plain aquifer discharges into Snake River via springs at American Falls Reservoir and springs in the Hagerman Valley, as indicated on Figure A. Through study of the effect of the flow net, it is estimated that of the water reaching the ground-water aquifer from the St. Anthony infiltration fields, 35 percent would return as inflow to American Falls Reservoir, with the remaining 65 percent returning to Snake River in Hagerman Valley. Of the water diverted for recharge near Idaho Falls, 65 percent would return to American Falls Reservoir, and 35 percent would return in Hagerman Valley. Of the water diverted for recharge in the Gravel Pit area, 70 percent would return as inflow to American Falls and the remainder would return to Snake River in Hagerman Valley.

## PROJECT BENEFITS

### Irrigation Benefits

The annual irrigation benefit for the Snake Plain Recharge Project has been estimated at $270,000. This irrigation benefit has been limited to the benefit associated with an additional supplemental water supply for presently irrigated lands above Milner of $253,000, and saving in irrigation pumping power charges for lands irrigated by ground-water wells of $17,000. Irrigation benefits associated with ground-water exchange pumping during dry periods for presently irrigated and new-land development, and the stabilization of ground-water




AVERAGE REDUCTION IN PUMPING HEAD IN FEET
DURING IRRIGATION SEASON FOR 1928-1957

Figure B

levels that could lead to somewhat earlier development of arable lands would be small in monetary values and have not been analyzed.

Irrigation Benefits from Supplemental Water

Most of the present irrigators above Milner depend upon diversions from the Snake River and its tributaries for an irrigation water supply. Water-supply studies for Palisades Project Report, dated June 1949, indicated a total irrigation water shortage of about 3,400,000 acre-feet with Palisades Reservoir in operation in the 24-year study period 1919 through 1942. This shortage would have occurred during the dry period in the 1930's. This study did not include water shortages for lands irrigated from the Henrys Fork.

Since this water study was made, land-use changes have occurred which would increase the water requirement. Lands within the irrigation districts have been leveled and otherwise improved so that they can be more intensively farmed. Cropping patterns have become more intense and, with a larger proportion of the irrigated land in row crops, the lands require larger late-season diversion. Also, crop yields have increased through better farming practices and technological improvements, resulting in an increased water requirement. If a specific analysis were made today, the irrigation shortages would undoubtedly be found to be larger than the 3,400,000 acre-feet indicated by this previous study. In a recent reconnaissance water-supply study made for Teton Basin Project, total water shortages for lands irrigated from the Henrys Fork were estimated at 1,700,000 acre-feet during the period 1928 through 1957. A large proportion of this shortage occurred during the dry 1930 period.

Any additional inflow to the Snake River above Milner during dry periods resulting from artificial recharge in wet years could be used through system operation to reduce irrigation shortages for the presently irrigated lands.

Average annual diversions to the three recharge areas are shown in table 17.

It has been estimated that about 35 percent of the St. Anthony, 65 percent of the Idaho Falls, and 70 percent of the Idaho Falls-Blackfoot Gravel Pit diversion would return as inflow to the river above Milner, and the remainder would return to the Snake River between Milner and Bliss. Applying these estimated inflows above Milner to average annual diversions outlined in table 17, the annual inflows as shown in table 18 would be available to meet irrigation water requirements above Milner.

Table 17.--Average annual diversion

| Recharge Area | Present Condition | Teton Basin 1/ Project and Burns Creek | Future 2/ Level of Development |
|---|---|---|---|
| | Acre-feet | Acre-feet | Acre-feet |
| St. Anthony | 100,000 | 83,000 | 58,000 |
| Idaho Falls | 200,000 | 165,000 | 80,000 |
| Gravel Pits | 15,000 | 13,000 | 10,000 |
| TOTAL | 315,000 | 261,000 | 148,000 |

1/ Assuming development of Teton Basin and Burns Creek Projects.
2/ Future development as outlined in the Upper Snake River Basin Report.

Table 18.--Average annual inflows above Milner

| Recharge Area | Present Condition | Teton Basin Project and Burns Creek | Future Level of Development |
|---|---|---|---|
| | Acre-feet | Acre-feet | Acre-feet |
| St. Anthony | 35,000 | 29,000 | 20,000 |
| Idaho Falls | 130,000 | 107,000 | 52,000 |
| Gravel Pits | 10,000 | 9,000 | 7,000 |
| TOTAL | 175,000 | 145,000 | 79,000 |

For the benefit analysis of this report, the depletion for the Teton Basin Project and Burns Creek has been assumed. Under this assumption, about 4,350,000 acre-feet of additional inflow during the 30-year study would return to Snake River above Milner from the Snake Plain aquifer. Of this amount, an estimated 900,000 acre-feet would be available in dry years to supplement the present irrigation water supply, and the balance would be available in years when it would be surplus to irrigation needs. During the 30-year study period, the average annual reduction in irrigation shortage would be about 30,000 acre-feet. Under future level of development, about 2,370,000 acre-feet of additional inflow would be available, and an estimated 490,000 acre-feet would be used in dry years to supplement the irrigation water supply, or an average annual reduction in irrigation shortage of about 16,000 acre-feet. The irrigation benefit for one acre-foot of supplemental water would be $12.20, based on long-term average prices expected to prevail, with an index of 250 (1910-14 equals 100) and cost index of 265 (1910-1914 equals 100).

With an average annual reduction in irrigation shortages of 30,000 acre-feet, the irrigation benefit would be $366,000 annually and $195,000 annually under future level of development. However, inflows into the Snake River from recharge could not be expected to reach a peak for a considerable length of time because of the comparatively great distance recharged water must move to points of discharge. Conversely, the effect of reduced diversions to the recharge area in dry years would not be reflected in inflows to the river from the aquifer for some time. Therefore, it has been necessary to determine the irrigation benefit as yearly averages.

Under the assumptions that maximum inflow to the Snake River would not be reached until the 25th year after initial recharge and gradually reduced from the 50th to the 100th year, because of decreased diversions to the recharge area, the average annual equivalent irrigation benefit would be $253,000. The reduction in amount of the diversion from the 25th to the 100th year is expected as a result of greater utilization of Milner spills for projects of the future in the Upper Snake River Basin.

## Irrigation Benefits from Reduced Cost of Ground-water Pumping

Of the 420,000 acres of lands now irrigated by ground water within the area of recharge influence, about 240,000 acres would be benefited by the effect of recharge on the water table. An additional estimated 250,000 acres served directly from ground water could be developed in the overall area in the future. The existing and future irrigation of these lands would benefit from recharge of the Snake Plain to the extent of savings that would result from rise in the water table and the accompanying reduction in pump lift. The rise in the water level would not occur uniformly over the entire area as illustrated on Figure B.

Based on the estimated average rise in the water table, annual saving in pumping power for ground-water pumping would be $10,200 for the land presently irrigated by pumping, as shown on table 19, and $10,900 for lands that could be irrigated by pumping in the future, as shown on table 20. Under future level of development, this saving

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Table 19.--Estimated annual saving in pumping power on lands presently irrigated by ground-water pumping

| Item | Unit | Miles from Recharge Area | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | |
| St. Anthony Recharge Area | | | | | | | |
| Irrigated from ground water (3.0 AF/Acre) | Acre | - | 12,900 | 14,700 | 21,200 | - | 48,800 |
| Annual pumping | Acre-ft. | - | 38,700 | 44,100 | 63,600 | - | 146,400 |
| Reduced pump lift | Feet | - | 2.0 | 1.2 | 0.8 | - | - |
| Total number of acre-feet raised 1 foot | Acre-ft. | - | 77,400 | 52,900 | 50,900 | - | 181,200 |
| Idaho Falls and Gravel Pit Recharge Area | | | | | | | |
| Irrigated from ground water (3.25 AF/A) | Acre | 15,900 | 41,700 | 64,000 | 53,700 | 15,900 | 191,200 |
| Annual pumping | Acre-ft. | 51,700 | 135,500 | 208,000 | 174,500 | 51,700 | 621,400 |
| Reduced pump lift | Feet | 6.0 | 3.3 | 2.0 | 1.3 | 0.8 | - |
| Total number of acre-feet raised 1 foot | Acre-ft. | 310,200 | 447,200 | 416,000 | 226,800 | 41,400 | 1,441,600 |
| Total reduction in pumping lift (1 foot) | Acre-ft. | - | - | - | - | - | 1,622,800 |
| Estimated saving | | | | | | | |
| Kw.-hr. 1/ | Kw.-hr. | | | | | | 2,559,000 |
| Value 2/ | Dollar | | | | | | 10,200 |

1/ Estimated pump efficiency of 65 percent.

2/ Estimated average cost of energy 4.0 mills/kw.-hr.

Table 20.--Estimated annual saving in pumping power on lands that could be irrigated by ground-water pumping in the future

| Item | Unit | Miles from Recharge Area | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | |
| St. Anthony Recharge Area | | | | | | | |
| Irrigated from ground water (3.0 AF/A) | Acre | - | 27,000 | 31,000 | 17,000 | - | 75,000 |
| Annual pumping | Acre-ft. | - | 81,000 | 93,000 | 51,000 | - | 225,000 |
| Reduced pumping lift | Feet | - | 2.0 | 1.2 | 0.8 | - | - |
| Total number of acre-feet raised one foot | Acre-ft. | - | 162,000 | 111,600 | 40,800 | - | 314,400 |
| Idaho Falls and Gravel Pit Recharge Area | | | | | | | |
| Irrigated from ground water (3.25 AF/A) | Acre | 18,000 | 61,000 | 33,000 | 23,000 | 37,000 | 172,000 |
| Annual pumping | Acre-ft. | 58,500 | 198,200 | 107,200 | 74,800 | 120,200 | 559,000 |
| Reduced pumping lift | Feet | 6.0 | 3.3 | 2.0 | 1.3 | 0.8 | - |
| Total number of acre-feet raised one foot | Acre-ft. | 351,000 | 654,100 | 214,400 | 97,200 | 96,200 | 1,412,900 |
| Total reduction in pumping lift (1 foot) | Acre-ft. | | | | | | 1,727,300 |
| Estimated saving | | | | | | | |
| Kw.-hr. 1/ | Kw.-hr. | | | | | | 2,724,000 |
| Value 2/ | Dollar | | | | | | 10,900 |

1/ Estimated pump efficiency of 65 percent.

2/ Estimated average cost of energy 4.0 mills/kilowatt-hour.

would be reduced to $5,800 and $6,200, respectively. Under the assumptions that diversion to recharge areas would average 261,000 acre-feet annually for the first 25 years and reduce gradually from the 25th to the 100th year, when future level of development would be reached, the average annual equivalent saving in pumping power would be $9,400 for the lands presently irrigated by ground-water pumping. Based on the assumption that of the lands that could be irrigated by ground-water pumping in the future, about 250,000 acres would be irrigated by the 25th year and assuming diversion to the recharge areas outlined above, the average annual equivalent saving in pumping power for ground-water pumping would be $7,200 or a savings of about $16,600 (rounded to $17,000) for lands presently irrigated by ground-water pumping and those that could be irrigated by ground-water pumping in the future.

## Flood Control Benefits

The Corps of Engineers has estimated the flood-control benefits associated with different size recharge canals and various degrees of development. The average annual benefits for a 2,000 cubic foot per second recharge canal at St. Anthony and a 2,500 cubic foot per second canal at Idaho Falls, for two conditions of possible future development, follow.

| Recharge Area | Existing System Plus Burns Creek | | Existing System Plus Burns Creek Plus 235,000 AF Storage on Teton River | |
|---|---|---|---|---|
| | Without Levees* | With Levees* | Without Levees* | With Levees* |
| St. Anthony | $94,500 | $52,050 | $29,580 | $24,400 |
| Idaho Falls | $16,480 | | $ 7,150 | |
| Combined | | | $ 34,250 1/ | $29,070 |

* Levees proposed for the Heise-Roberts Extension Flood-Control Project would protect lands along Henrys Fork from its mouth to Texas Slough from a flood of 11,500 c.f.s. and along Snake River from Henrys Fork to the Roberts Bridge from a flood of 33,000 c.f.s.

1/ Rounded to $34,000

The Corps of Engineers also advises that recharge diversions would receive some downstream benefits on Lower Columbia River as described in the Upper Snake River Basin studies. Those benefits would amount to about $39,000 annually. A flood-control benefit of $73,000 ($39,000 plus $34,000) has been used in this reconnaissance analysis.

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Project Functions and Accomplishments

Copy of a letter from the Corps of Engineers, dated July 20, 1961, covering project flood-control aspects, is appended.

## Power Benefits

With the addition of Teton Basin Project and Burns Creek to the present system, water would be divertible for recharge on an average of nearly 46 days per year at an average rate of 2,860 cubic feet per second. After an initial stabilization period, inflows to American Falls and below Milner would average 190 and 310 cubic feet per second, respectively. These figures have been reduced to reflect additional irrigation depletion during dry years.

After adjustments were made for powerplants presently operating at high plant factors, the energy potential of the net change in flows through all downstream powerplants, existing and under construction, was computed. Increased flows were assumed usable 80 percent of the time, except at plants where studies indicate lesser values should be used.

With the Teton Basin Project and Burns Creek added to the present development, the Snake Plain Recharge Project would have the following effect.

| | | |
|---|---|---|
| Energy production due to increased flows | - | 265,000,000 kw.-hrs. |
| Energy reduction due to decreased flows | - | 78,000,000 kw.-hrs. |
| Net average annual increase | - | 187,000,000 kw.-hrs. |

Under future conditions, water would be diverted for recharge on an average of nearly 33 days per year at an average rate of 2,240 cubic feet per second. After adjustment to reflect increased irrigation depletion in dry years, inflows to American Falls, and below Milner would average 100 and 190 cubic feet per second, respectively. Energy potential of these increased flows through all downstream head contemplated for development was computed. Except for plants where studies indicated the use of a lesser value, increased flows were assumed usable for energy production 95 percent of the time. Under these conditions, the Snake Plain Recharge Project would have the following effect:

| | | |
|---|---|---|
| Energy production due to increased flows | - | 326,000,000 kw.-hrs. |
| Energy reduction due to decreased flows | - | 260,000,000 kw.-hrs. |
| Net average annual increase | - | 66,000,000 kw.-hrs. |

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For determination of the annual power benefits, credit has only been taken for the average annual energy produced at the powerplants. The energy value used is the Federal Power Commission Southern Idaho at-site value of 3.4 mills per kilowatt-hour. Applying this value to the increased energy anticipated, the annual average equivalent power benefit would be $636,000 (187,000,000 kw.-hr. at 3.4 mills/kw.-hr.) under present conditions plus Teton Basin Project and Burns Creek and under future conditions $224,000 (66,000,000 kw.-hr. at 3.4 mills/kw.-hr.). Assuming an initial stabilization period of 25 years and smaller diversions to the recharge area from the 25th to the 100th year when future conditions would be reached, the estimated annual average equivalent power benefit for the 100-year period would be $430,000.

## Fish and Wildlife

The fish and wildlife aspects of the Snake Plain Recharge Project have been evaluated by the U. S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. Reports for both the St. Anthony and Idaho Falls Recharge areas were prepared by the Service, and a copy of each report, dated May 31, 1961 and November 20, 1961, respectively, is appended.

Fish-screen structures with rotary-type screens and by-pass conduits have been provided in the cost estimates for both the St. Anthony and Idaho Falls Recharge areas.

Concrete fish ladders also have been included in the development plan for both areas. However, the U. S. Fish and Wildlife Service and the State of Idaho Department of Fish and Game have not, as yet, reached full agreement on the necessity of such fish-passage facilities around the diversion structure in the Idaho Falls Recharge area.

It has also been suggested that flows adequate to permit fish to reach spawning areas be provided during the spring season, but the amount of flow needed has not, as yet, been determined by the Service.

The Fish and Wildlife Service, in commenting on wildlife in the recharge areas, points out that diversion of spring runoff might adversely affect downstream wildlife habitat by reducing high spring flows which ordinarily replenish the existing wetlands, and therefore recommends that flows sufficient to maintain the present state of these areas be provided by the project plan.

It has been found, however, that subirrigation practices along Henrys Fork contribute substantially to perched water tables that in turn maintain levels in many of the marshy areas involved. Further detailed study is necessary to determine the relationship between

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floodflows and subirrigation recharge practices and to more specifically define the areas subject to improvement.

The Service, in commenting upon the positive features of recharge, points out that both Federal and State fish hatcheries in the Thousand Springs area would benefit if flows from the Snake Plain aquifer were increased as a result of the project and continue to maintain their present quality. It is also pointed out that the intermittent ponds established by recharge, at times, would benefit migrating waterfowl.

## Pollution Abatement

The U. S. Public Health Service, Division of Water Supply and Pollution Control, Department of Health, Education and Welfare, has prepared a preliminary evaluation report relative to the significance of the project from the standpoint of the Public Health Service. This report of April 16, 1962 is appended, and recommends that the following investigations be carried out, if the Snake Plain Recharge Project proceeds beyond the reconnaissance level:

1. Studies be done to establish water-quality criteria which would be satisfactory for ground-water recharge at specific recharge sites. The quality criteria would be dependent upon the degree of filtration and pollutant removed obtained at each recharge area, the projected municipal and domestic use of ground water adjacent to each recharge area, and the physical, chemical, and bacteriological quality of the surface waters used for recharge.

2. Studies to determine movement of ground water in the specific areas considered for ground-water recharge.

3. An evaluation of the low flow augmentation benefits which could be satisfied by this project.

# F I N A N C I A L   A N A L Y S I S

## ECONOMIC JUSTIFICATION

The Snake Plain Recharge Project has economic justification. In a 100-year period of analysis, annual benefits exceed annual costs by a ratio of 2.00 to 1.00.

Annual benefits for the project would total $773,000. This consists of the irrigation benefit of $270,000, the power benefit of $430,000, and the flood-control benefit of $73,000.

The net Federal investment for the Snake Plain Recharge Project would be $13,359,000. This amount was derived by adding to the construction cost($13,150,000), interest during construction ($329,000), and deducting the cost of past investigations ($120,000).

The annual equivalent cost of the Snake Plain Recharge Project over a 100-year period of analysis is $386,000. This cost includes the annual equivalent cost of the net Federal investment ($13,359,000) over a 100-year period at 2-1/2 percent interest ($365,000) and the annual operation and maintenance cost ($21,000).

Annual benefits of the Snake Plain Recharge Project ($773,000) would exceed the annual project cost ($386,000) by a ratio of 2.00 to 1.00 over a 100-year period of analysis.

## ALLOCATION OF COSTS

The development plan of the Snake Plain Recharge Project would benefit irrigation, power, and flood control. It is necessary to allocate or assign construction and operating costs to the function served.

Project facilities include $430,000 for fish screens and fish ladders at the St. Anthony Recharge area, and $625,000 for fish screens and fish ladders at the Idaho Falls Recharge area. This total construction cost of $1,055,000, and the annual operation and maintenance cost of $1,000, is associated with mitigating fish and wildlife losses. These costs have been assigned to fish and wildlife. Deducting these assigned costs from the total project cost of $13,150,000 and the annual operation cost of $21,000, leaves a $12,095,000 construction cost and a $20,000 annual operating cost to be allocated under the separable cost-remaining benefit method of allocation.

The cost of $12,095,000 to be allocated, and interest during construction totaling $303,000, amortized over a 100-year period at 2-1/2 percent interest, amounts to annual equivalent costs of $330,300 and $8,300, respectively. Addition of the $20,000 operating cost would give a total annual equivalent cost of $358,600 to be allocated.

## Financial Analysis

Annual benefits of $270,000 for irrigation, $430,000 for power, and $73,000 for flood control used in the allocation were derived previously.

The most economical single-purpose alternates for all three functions served would be the project as proposed with an annual equivalent cost of $358,600.

There would be no separable costs associated with the three functions served.

Derivation of the allocation and assignment of costs to the functions served are presented in table 21.

## REPAYMENT

The Snake River Plain comprises a geographic area of about 13,000 square miles, and has a population of over 250,000 people. Most of the people in this area now have, either directly or indirectly, an economic and water-supply dependence on ground water. Uses are widely varied, including domestic, municipal, irrigation, power, recreation, industrial, fish and wildlife, commercial fish propagation, pollution abatement, atomic energy programs and aesthetics. The degree of dependence on utilization of ground water varies greatly among the individual users within each grouping. Further, there are substantial differences in the characteristics of each of the main categories of ground-water usage. Specific needs for ground water fluctuate from day to day, season to season, and from periods of surface water abundance to drought years.

Augmenting the underground water resource of Snake Plain with surplus water from Henrys Fork and Snake River has many and specific values. The direct and indirect beneficiaries would number well over one hundred thousand people. The purposes benefited would extend in some degree, and in differing ways, across the entire spectrum of economic activity in the area. In addition, benefits accruing from the project functions of power and flood control would extend far beyond the geographic limits of the Snake River Plain.

While the overall benefits over a long period of time from artificial recharge are susceptible to determination, the contributions from recharge to an individual ground-water user in a specific location cannot be accurately measured. Hence, contracting with the great number of entities who might be involved for payment of reimbursable costs on the basis of an assured and measurable ground-water benefit associated with each is recognized as impractical.

Table 21.--Allocation of costs

| Items | Irrigation | Power | Flood Control | Fish & Wildlife | Recreation | Total |
|---|---|---|---|---|---|---|
| **Total Costs:** | | | | | | |
| Construction | | | | | | $13,150,000 |
| Interest during construction | | | | | | 329,000 |
| Operation and maintenance | | | | | | 21,000 |
| Replacements | | | | | | -- |
| **Assigned Costs:** | | | | | | |
| Construction | | | | $1,055,000 | | 1,055,000 |
| Interest during construction | | | | 26,000 | | 26,000 |
| Operation and maintenance | | | | 1,000 | | 1,000 |
| Replacements | | | | -- | | -- |
| **Costs to be Allocated:** | | | | | | |
| 1. Annual construction costs | | | | | | 330,300 |
| 2. Annual interest during const. | | | | | | 8,300 |
| 3. Operation and maintenance | | | | | | 20,000 |
| 4. Replacements | | | | | | -- |
| Total | | | | | | 358,600 |
| **Benefits** | $270,000 | $430,000 | $ 73,000 | | | 773,000 |
| **Alternate Costs** | 358,600 | 358,600 | 358,600 | | | -- |
| **Justifiable Expenditure** | 270,000 | 358,600 | 73,000 | | | 701,600 |
| **Separable Costs:** | | | | | | |
| 1. Annual construction costs | | | | | | |
| 2. Annual interest during const. | | | | | | |
| 3. Operation and maintenance | | | | | | |
| 4. Replacements | | | | | | |
| Total | 0 | 0 | 0 | | | 0 |
| **Remaining Justifiable Expenditure** | 270,000 | 358,600 | 73,000 | | | 701,600 |
| **Percent Distribution** | 38.5 | 51.1 | 10.4 | | | 100 |
| **Remaining Joint Costs:** | | | | | | |
| 1. Annual construction costs | $126,900 | $169,000 | $34,400 | | | $330,300 |
| 2. Annual interest during const. | 3,200 | 4,200 | 900 | | | 8,300 |
| 3. Operation and maintenance | 8,000 | 10,000 | 2,000 | | | 20,000 |
| 4. Replacements | -- | -- | -- | | | -- |
| Total | 138,100 | 183,200 | 37,300 | | | 358,600 |
| **Total Allocated Costs:** | | | | | | |
| 1. Annual construction costs | 126,900 | 169,000 | 34,400 | | | 330,300 |
| 2. Annual interest during const. | 3,200 | 4,200 | 900 | | | 8,300 |
| 3. Operation and maintenance | 8,000 | 10,000 | 2,000 | | | 20,000 |
| 4. Replacements | -- | -- | -- | | | -- |
| Total | 138,100 | 183,200 | 37,300 | | | 358,600 |
| Total Allocated & Assigned Costs | | | | | | |
| 1. Construction costs | 4,647,000 | 6,188,000 | 1,260,000 | 1,055,000 | | 13,150,000 |
| 2. Interest during construction | 117,000 | 153,000 | 33,000 | 26,000 | | 329,000 |
| 3. Operation and maintenance | 8,000 | 10,000 | 2,000 | 1,000 | | 21,000 |
| 4. Replacements | -- | -- | -- | -- | | -- |

## Financial Analysis

Snake Plain Recharge Project, by its nature, presents many unusual and unconventional considerations. The physical and technical problems of identifying the water for recharge, delivering such water underground, and predicting the overall effects and benefits of recharge, lend themselves to analysis and eventual solution. The accomplishment of this long-range beneficial water use rests to a great degree with all of the people in the area involved, for this group as a whole, are the project's direct beneficiaries. As such, they logically would have to undertake the repayment of reimbursable costs, in some acceptable manner, for the project to be built.

A possibility for repayment of some component of the recharge project is suggested by the relationship of future project uses of ground water to recharge. Projects of the future depending on ground-water exchange or replacement might properly incorporate a degree of artificial recharge commensurate with the quantities of new ground-water development involved, location of the points of ground-water withdrawal, and possible influences that such new uses would have on existing ground-water pumping.

The solutions to the many compelling problems associated with obtaining repayment under such circumstances are far beyond the scope of this report. The project functions of power, and municipal and industrial water, are normally cost components requiring repayment with interest, a factor not yet accounted for. Some overall organization within the framework of Idaho State law probably would be required. These are among the many unanswered questions. Nevertheless, the soundness of the artificial recharge concept and its contribution to a fuller beneficial use of indispensable water would certainly seem to justify efforts necessary to achieve repayment.

# CONCLUSIONS

It is concluded that:

(1) Substantial quantities of water are available in Snake River and tributaries above Milner Dam in most years for artificial recharge of the aquifers of the Snake River Plain.

(2) Such diversion would be a beneficial employment of valuable water resources that would otherwise leave this area unused.

(3) The Snake Plain offers an excellent opportunity for recharge operations. The large, little-used, relatively flat areas present a surface of exposed basalts that take water readily and transmit it relatively rapidly from the ground surface to the water table, and the aquifer has high coefficients of transmissibility and storage.

(4) Water artificially recharged would augment a ground-water resource now subject to practical utilization in many locations.

(5) The development plan has engineering feasibility and economic justification, with benefits exceeding costs by a ratio of 2.00 to 1.00 over a 100-year period of analysis.

(6) The artificial recharge project is well suited to development in stages, or increments, over a long period of time.

(7) A solution to the aspects of repayment of reimbursable project costs is not possible at this time.

# APPENDED MATERIAL

U. S. ARMY ENGINEER DISTRICT, WALLA WALLA, Corps of Engineers, Walla Walla, Washington
Letter of July 20, 1961

DEPT. OF HEALTH, EDUCATION, AND WELFARE, Regional Office, Region IX, Public Health Service, Water Supply and Pollution Control Program, Pacific Northwest, Portland, Oregon
Letter of April 16, 1962 with attached statement

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Portland, Oregon
Reconnaissance report dated May 31, 1961
Supplement to May 31, 1961 report dated November 20, 1961

Bureau of Mines, Albany, Oregon
Letter dated September 26, 1961

Geological Survey, Water Resources Division, Ground Water Branch, Boise, Idaho
Report on Feasibility of Artificial Recharge in the Snake River Basin, Idaho - 1962

U. S. ARMY ENGINEER DISTRICT, WALLA WALLA
CORPS OF ENGINEERS
Bldg. 602, City-County Airport
Walla Walla, Washington

20 July 1961

Mr. David Crandall
Area Engineer
Bureau of Reclamation
Snake River Development Office
214 Broadway
Boise, Idaho

Dear Mr. Crandall:

In response to your letters of 14 September 1960 and 11 May 1961, the average annual benefits from the Snake River Plain Recharge have been calculated, using 1960 price level and conditions, unless otherwise designated.

Regulation by the present system of Jackson Lake and Palisades Reservoir plus the proposed Burns Creek Reservoir, for joint use flood control purposes is assumed. Frequency estimates are based on existing irrigation diversions. Flood control benefits are calculated from the point of diversion to the head of American Falls Reservoir. Other conditions involved are described, as relating to each point of diversion, in the following paragraphs.

1. The average annual benefits for three different diversions from Henrys Fork at St. Anthony are as follows:

| | Diversion | | |
|---|---|---|---|
| Existing System Plus Burns Creek | 1,500 cfs | 2,000 cfs | 2,500 cfs |
| Without levees 1/ | $75,230 | $ 94,500 | $106,460 |
| With levees 1/ | 40,300 | 52,050 | 58,770 |
| Existing System Plus Burns Creek and 235,000 Acre-Feet Storage on Teton River | | | |
| Without levees 1/ | $ 24,440 | $ 29,580 | $ 34,950 |
| With levees 1/ | 19,890 | 24,400 | 28,500 |

2. The average annual benefits for three different diversions from Snake River at the Great Western Canal diversion, with 2,000 cfs diversion from Henrys Fork at St. Anthony and 235,000 acre-feet of storage in Fremont and Driggs Reservoirs on lower Teton River, are as follows:

| | Diversions | | | |
|---|---|---|---|---|
| | 1,500 cfs | 2,000 cfs | 2,500 cfs | 1,800 cfs |
| Without levees 1/ | $ 32,640 | $ 33,560 | $ 34,250 | $ 33,190 |
| With levees 1/ | 27,460 | 28,380 | 29,070 | 28,010 |

1/ Levees proposed for the Heise-Roberts Extension flood control project would protect lands along Henrys Fork from its mouth to Texas Slough from a flood of 11,500 cfs and along Snake River from Henrys Fork to the Roberts Bridge from a flood of 33,000 cfs.

3. The average annual benefits for the three different diversions from Snake River at the Great Western Canal heading are as follows:

| | Diversions | | |
|---|---|---|---|
| | 1,500 cfs | 2,000 cfs | 2,500 cfs |
| Existing System Plus Burns Creek | $ 9,650 | $ 14,360 | $ 16,480 |
| Existing System Plus Burns Creek and 235,000 Acre-Feet Storage on Teton River | 4,470 | 5,650 | 7,150 |

4. The average annual benefits for three different diversions from Snake River about three miles above Firth are as follows:

| | Diversions | | |
|---|---|---|---|
| | 1,500 cfs | 2,000 cfs | 2,500 cfs |
| Existing System Plus Burns Creek | $ 5,590 | $ 8,270 | $ 9,480 |
| Existing System Plus Burns Creek and 235,000 Acre-Feet Storage on Teton River | 2,530 | 3,190 | 4,030 |

No flood control benefits for the area above American Falls Reservoir would be earned by diversions from Snake River at the Milner-Gooding Canal as the canal heading is downstream from that area.

All of the diversion would receive some downstream flood control benefits on lower Columbia River as described in the Upper Snake River studies. Slight improvement of flood conditions on Snake River near Weiser might also be afforded.

Damages in the area are to irrigated agricultural lands, rural residences, roads, highways, bridges, irrigation and drainage works, the community of Roberts, and other improvements. Land damages, crop losses, fences, farm buildings and improvements are some of the agricultural damages. Flood fighting, evacuation and relief costs are involved in large floods. These proposed diversions provide limited flood control benefits by reduction of flood peaks.

All calculations are derived from damages used in the Upper Snake River study, modified to reflect the change, in frequencies for the various diversions.

Average annual benefits for future growth are not shown as this evaluation is for initial conditions only.

Sincerely yours,

(Sgd.) J. H. Beddow

J. H. BEDDOW
Colonel, CE
District Engineer

Copy

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
IX

PUBLIC HEALTH SERVICE
Water Supply and Pollution Control
Program, Pacific Northwest
Room 570 Pittock Block
Portland 5, Oregon

April 16, 1962

Mr. D. L. Crandall, Area Engineer
Snake River Development Office
Bureau of Reclamation
214 Broadway
Boise, Idaho

Dear Mr. Crandall:

Enclosed is our statement on the Snake Plain Recharge Project, and I trust that it will be satisfactory for incorporation into your reconnaissance report. As you will note, we do not have sufficient information at this time to fully evaluate the public health and water quality aspects associated with the artificial recharge of the ground water basin. We have, however, identified specific investigations which should be carried out when the project advances to a project investigation study.

We have discussed this project with the State Sanitary Engineer of Idaho, and he has indicated the desirability of a detailed study to better evaluate the effect of this project on the quality of domestic and municipal water supplies in the area.

If we can be of further assistance to you in connection with this project, please do not hesitate to call on us.

Sincerely yours,

(Sgd.)

W. W. Towne, Director
Columbia River Basin Project

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Regional Office
IX

PUBLIC HEALTH SERVICE
Water Supply and Pollution Control
Program, Pacific Northwest
Room 570 Pittock Block
Portland 5, Oregon

## STATEMENT ON THE SNAKE PLAIN RECHARGE PROJECT

The U. S. Public Health Service, Division of Water Supply and Pollution Control, Department of Health, Education, and Welfare has completed a preliminary evaluation of the Snake Plain Recharge Project which is under investigation by the U. S. Bureau of Reclamation. The purpose of the reconnaissance investigation by the Bureau of Reclamation is to analyze the possibilities of introducing surplus flows of the Snake River into the Snake Plain aquifer for the purposes of flood control, stabilization of river flows for power production, and sustaining ground water levels for present uses and for the expansion of irrigation from ground water.

The investigation has considered diversions of surface water into the ground water basin at recharge sites located at St. Anthony, Idaho Falls and the Idaho Falls-Blackfoot area.

The Snake Plain Recharge Project is of significance to the U. S. Public Health Service for two reasons: (1) the potential pollution of the ground water in the Snake Plain aquifer resulting from the introduction of untreated surface water, and (2) the effect this project would have on the management and use of surface waters in the upper Snake River in relation to the maintenance of minimum flows for water quality control.

The preliminary study and evaluation of the Snake Plain Recharge Project has shown that there is not sufficient data and information available to accurately determine the effect of recharge at the specific sites considered; however, a general evaluation is as follows:

St. Anthony Recharge Sites--The surplus flow from Henry's Fork which would be used for recharge is relatively unpolluted from municipal and industrial wastes and the quality appears to be equal to other surface waters which recharge the ground water basin naturally. Serious pollution of the ground water at this site due to recharge appears remote, provided that the present quality of Henry's Fork is maintained.

Idaho Falls Area--Both municipal and industrial wastes are discharged into the Snake River above the diversion for recharge at this site. The present and future quality of the surface waters must be considered as a potential threat to the quality of the ground water basin. Additional study is definitely needed to determine the feasibility of recharge at this site.

Idaho Falls-Blackfoot Gravel Pit Recharge Site--The Snake River between Idaho Falls and Shelly presently receives municipal and industrial wastes with a population equivalent of approximately 500,000 persons and future industrial and population expansion will result in additional waste discharges. In the future, the water of the Snake River in this reach is anticipated to be of unsatisfactory quality for ground water recharge. The domestic and municipal use of ground water in this area is very high and maintenance of the ground water quality is considered paramount. The feasibility of recharge at this site is considered doubtful.

At the present time, the complex management and regulation of the Snake River has resulted in minimum flows especially during the winter which are not sufficient to assimilate the municipal and industrial waste discharges above Milner Dam. Under present conditions water quality objectives in the Snake River cannot be met. Since the Snake Plain Recharge Project considers excess flood flows which only occur approximately five years in ten, the project when considered by itself would be of little value for low flow augmentation. However, the possibility of ground water exchange made possible by this project for surface waters available each year for low flow augmentation would be beneficial for water quality control.

It is recommended that the following investigations be carried out if the Snake Plain Recharge Project proceeds beyond the reconnaissance level:

1. Studies be done to establish water quality criteria which would be satisfactory for ground water recharge at specific recharge sites. The quality criteria would be dependent upon the degree of filtration and pollutant removed obtained at each recharge area, the projected municipal and domestic use of ground water adjacent to each recharge area, and the physical, chemical, and bacteriological quality of the surface waters used for recharge.

2. Studies to determine movement of ground water in the specific areas considered for ground water recharge.

3. An evaluation of the low flow augmentation benefits which could be satisfied by this project.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Bureau of Sport Fisheries and Wildlife
1001 N. E. Lloyd Blvd.
P. O. Box 3737
Portland 8, Oregon

May 31, 1961

Memorandum

To: Regional Director, Bureau of Reclamation
Boise, Idaho

From: Regional Director, Bureau of Sport Fisheries and Wildlife

Subject: Snake Plain Recharge Project, Idaho

This is our Bureau's reconnaissance report on effects Snake Plain Recharge Project would have on fish and wildlife. We have reviewed pertinent information contained in the joint report of your Bureau and the Corps of Engineers, entitled "Preliminary Summary Report, Upper Snake River Basin, Wyoming-Idaho-Utah-Nevada-Oregon," dated November 1960, and additional and revised data furnished by your Snake River Development Office through January 1961. The following statements pertaining to measures for conservation and development of fish and wildlife resources are submitted for early consideration in your planning. This report has been prepared in accordance with the Fish and Wildlife Coordination Act, (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It has been reviewed by the Idaho Department of Fish and Game and has the concurrence of that Department as indicated in a letter from Director Ross Leonard, dated April 21, 1961, a copy of which is attached.

Although the preliminary nature of your investigations does not permit conclusive statements regarding anticipated project effects on fish and wildlife resources, information provided is sufficient to warrant making comments of a generalized nature. Further studies will be required before firm recommendations for conservation and development of fish and wildlife can be made. We will continue to maintain close liaison with the Snake River Development Office in our planning for fish and wildlife resources in connection with this project.

Snake Plain Recharge project area would encompass that portion of the Snake River Plain located principally north of Snake River between the Plain's upper topographic limits near Kilgore, Idaho, and the Thousand Springs area near Bliss, Idaho. Foothills of the Lost River Range, Lemhi Range, and the Centennial Mountains form a part of the northwest boundary of the Plain. The southern and eastern boundaries of the Plain would be the limit of the ground-water reservoir which in certain areas may extend beneath Snake River to the south. These limits have not been determined. The Plain is about 250 miles long, 60 to 70 miles wide, and encompasses about 13,000 square miles.

Snake River Plain comprises a hydraulic system in which aquifers of Snake River basalts and interbedded sediments serve both as a storage reservoir and a ground-water conduit. Tributary valleys contiguous to the Plain furnish the principal recharge to its aquifers.

At many places the irregular, broken surface of the Snake Plain lava takes water readily and large fractures and other openings permit rapid percolation of water into the ground-water reservoir. Principal natural discharge of water from the ground-water reservoir occurs in the Thousand Springs area, a reach of about 40 miles, in a canyon of Snake River between Twin Falls and Bliss, Idaho. In this stretch river flows increase by about 8,000 second-feet, of which 6,000 second-feet probably represents ground water discharged from Snake River Plain.

Snake Plain Recharge project is a plan for the introduction of surplus seasonal runoff and flood flows from various sections of Snake River and tributaries into Snake Plain aquifers for the purposes of flood control, stabilization of river flows for power production, and irrigation. This underground storage water would then spread over a wide area and flow from the recharge zone to a discharge area. Some water would be used on appropriate lands along the route. Irrigation benefits would accrue from sustained ground-water levels for present irrigation uses and development of new areas. Water would be used primarily for subsurface and surface irrigation. Water for surface irrigation would be secured by pumping from the ground-water reservoir.

It is our understanding that there are three areas in the Snake River Plain where recharge appears most practical; (1) the area near St. Anthony, lying west of Egin Bench, north of Menan Buttes, and extending westward between Market Lake and Mud Lake, mainly in Jefferson County and Fremont County, Idaho; (2) an area along the west side of Snake River between Idaho Falls and Shelley, mainly in Bingham County and Bonneville County, Idaho; and (3) an area lying north and east of American Falls Reservoir, between its backwaters and Blackfoot, Idaho, mainly in Bingham County, Idaho. Neither size nor locations of recharge diversions or of the recharge areas have been determined for the latter two possibilities. Accordingly, our comments apply specifically only to the St. Anthony area.

Water would be supplied to the St. Anthony recharge area from Henrys Fork Snake River by means of a canal originating in the diversion pool of existing Farmers Friend and St. Anthony Canals. The existing diversion dam is located about three miles upstream from St. Anthony on Henrys Fork Snake River. It is built in two sections at the dividing point of two river channels. The inlet of existing Farmers

Friend Canal is located on the east side of the river and the canal serves lands lying south of St. Anthony. Existing St. Anthony Canal leaves the river on the west side and serves lands lying west of St. Anthony. The inlet of the proposed canal would be located on the west side of Henrys Fork immediately upstream from the inlet of St. Anthony Canal. The proposed canal would be 17 miles long and would have a capacity of 2,000 second-feet. It would follow a course generally parallel to, but north of, St. Anthony Canal and would pass through several ponding areas and end in lava beds north of St. Anthony.

Your current plans call for a rotary-type fish screen in the proposed canal located about 50 feet below its intake. A 42-inch concrete outlet pipe located immediately upstream from the fish screen would permit movement of fish back into the river at a point downstream from the west section of the diversion dam. This outlet, several hundred feet in length, would pass under St. Anthony Canal.

Based on a maximum diversion of 2,000 second-feet from Henrys Fork Snake River at St. Anthony, an average of about 100,000 acre-feet of water could be diverted each year to the Snake Plain for ground-water recharge purposes. A maximum of about 356,000 acre-feet could be diverted in a year of extremely high runoff. No water would be available for recharge in dry years.

## Fisheries

Henrys Fork Snake River is well known for its excellent trout fishery. The river has a constant flow and rarely freezes over. Year-round fishing is available in the stretch of river near St. Anthony. Rainbow and cutthroat trout, and mountain whitefish are the principal game fish caught.

The water level of the river above the recharge diversion site has been raised by the existing diversion dams, creating an area wider and deeper than normal for the stream. This section is popular with fishing, boating, and picnicking parties. The river downstream from the diversion dam contains many islands and provides an excellent fishery.

Diversion of surplus and flood waters from Henrys Fork Snake River would stabilize downstream flows to the benefit of the fishery. However, complete elimination of flood and surplus flows would adversely affect spawning migrations, resulting in a net loss to fish with the project. High water permits fish to pass over obstacles which ordinarily cannot be surmounted. Flows adequate to permit fish to reach spawning areas should be provided during the spring season. The amount of flow needed has not been determined.

Fish may concentrate below the existing diversion dams on the river, especially downstream from the bypass outlet of the proposed diversion canal where they would be attracted by flows emanating from the pipe. Fish could not return to the diversion canal through the pipe because of high water velocities. Fish-passage facilities and sufficient attraction water should be provided to enable fish to pass over the west section of the dam. Fish-passage facilities should also be provided in the east section of the diversion dam.

It is our believe that a 42-inch bypass outlet pipe is larger than necessary for the return of fish to the west section of the river. A pipe of considerably smaller diameter would probably be sufficient if water velocities are high enough to prevent fish from remaining in the pipe. An advantage of the smaller pipe would be the reduction of attraction water at the bypass outlet which would reduce concentrations of fish in that area.

## Wildlife

Good waterfowl and fur-animal habitat are available in the section of the river near the diversion site. Waterfowl use, however, is moderately light since more desirable habitat is found downstream from St. Anthony and birds are attracted to that area. The river-bottom land downstream from St. Anthony contains some of the best wildlife habitat in eastern Idaho. Dense vegetative cover along the banks provides food and cover for wildlife. Meandering river flows, oxbow lakes, potholes, and marshy areas are used by muskrats, beavers, minks, river otters, and a variety of waterfowl. Canada geese, mallards, and redhead ducks nest in this sector. Mule and white-tailed deer are also present. A few moose use the area during the winter season.

Diversion of spring runoff would adversely affect downstream wildlife habitat by reducing high spring flows which ordinarily replenish the valuable wetlands. Nesting sites and food for waterfowl, and food for fur animals and big game, could be destroyed. The valuable wildlife habitat downstream from St. Anthony, in particular, could be seriously damaged. It is highly important that these areas be maintained in their present state. Flows sufficient to maintain these areas should be provided with the project.

It is possible that introduction of water into the Snake Plain aquifers would raise the water table sufficiently in the vicinity of Camas National Wildlife Refuge to benefit wildlife in that area. Additionally, wildlife in the State of Idaho North Lake Wildlife Management Area (Mud Lake) could be benefited by a raised water table. Hagerman National Fish Hatchery near the Thousand Springs area might be benefited if flows which are used to operate that hatchery are increased as a result of the project.

Fish and Wildlife Report

The recharge canal would pass through several ponding areas, three of which are now used for ground-water recharge purposes. These include Egin Lakes, Mackerts Pond, and Davis Lake. Egin Lakes consist of three ponds which hold spring runoff temporarily. Mackerts Pond and Davis Lake fill during the spring runoff period and retain water through most of the summer months. Additional water added to these ponds by the proposed recharge canal may provide some minor benefits to nesting waterfowl. Even with an additional supply Egin Lakes could not be expected to retain water for a long enough period to be beneficial to waterfowl. Other proposed ponding areas are expected to hold water only for short periods. However, if water should accumulate and remain on the surface for extended periods, waterfowl would be considerably benefited.

We appreciate the opportunity to participate in the early planning stages of this project. When additional plans and information become available, we would appreciate receiving them so that our investigations may continue concurrently with yours. In the event that Snake Plain Recharge project reaches feasibility status we will recommend that conservation and development of fish and wildlife resources be among the purposes for which authorization of the project is sought.

/s/ Paul T. Quick

S T A T E   O F   I D A H O

Robert E. Smylie
Governor

DEPARTMENT OF FISH AND GAME

April 21, 1961

Mr. Paul T. Quick
Regional Director
Bureau of Sport Fisheries and Wildlife
P. O. Box 3737
Portland 8, Oregon

Dear Mr. Quick:

Reference is made to your preliminary draft of a proposed report to the Regional Director, Bureau of Reclamation, Boise, regarding the Snake Plain Recharge Project in Idaho. Please be advised that this Department concurs with your report.

When additional plans and information become available we would appreciate reviewing them with you.

Sincerely yours,

/s/ Ross Leonard

Ross Leonard
Director

GENERAL MAP NOT REPRODUCED

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UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Bureau of Sport Fisheries and Wildlife
1002 N. E. Holladay Street
P. O. Box 3737
Portland 8, Oregon

November 20, 1961

Memorandum

To: Regional Director, Bureau of Reclamation
Boise, Idaho

From: Acting Regional Director, Bureau of Sport Fisheries and Wildlife, Portland, Oregon

Subject: Snake Plain Recharge Project, Idaho--Idaho Falls Recharge Area

The following is intended to supplement the Bureau of Sport Fisheries and Wildlife reconnaissance report issued May 31, 1961, on effects Snake Plain Recharge project would have on fish and wildlife. It is based on additional information recently received from your Snake River Development Office, and has been prepared in accordance with the Fish and Wildlife Coordination Act, (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). This supplement has been reviewed by the Idaho Department of Fish and Game and has the general concurrence of that Department as indicated in a letter from Director Ross Leonard dated October 6, 1961, a copy of which is attached. Mr. Leonard questions the need for fish passage facilities at the diversion dam. We agree with Mr. Leonard's suggestion for further study of this problem and our report has been revised to emphasize this.

Our comments in the reconnaissance report applied specifically to only that portion of Snake Plain Recharge project near St. Anthony, Idaho. This supplement is concerned only with the Idaho Falls recharge area. It is our understanding that your proposal for a recharge area near Blackfoot, Idaho has been found infeasible. We also understand that you are now investigating the possibility of diverting excess spring flows into various gravel pits between Idaho Falls and Blackfoot, where ground-water levels are lower than Snake River. This latter possibility and other recharge areas which are being considered will be discussed when more detailed information is available.

Although the preliminary nature of your investigations does not permit conclusive statements regarding anticipated project effects on fish and wildlife resources, information provided is sufficient to warrant making comments of a generalized nature. Further studies by our Bureau will be required before firm recommendations for conservation and development of fish and wildlife can be made. We will continue to maintain close liaison with your Bureau in our planning for fish and wildlife resources in connection with this project.

Fish and Wildlife Report

The Idaho Falls recharge area lies along the west side of Snake River between Idaho Falls and Shelley, mainly in Bonneville and Bingham Counties, Idaho. Surplus seasonal runoff and flood flows from Snake River would be introduced into the area through existing Great Western Canal which diverts water from Snake River about 9 miles north of Idaho Falls. A diversion dam across Snake River located about 400 yards below the mouth of Great Western Canal provides the head of water for this canal. Great Western Canal serves lands lying along Snake River west of Idaho Falls. It would be enlarged from its capacity of 700 second-feet to 2,500 second-feet to accommodate the increase in flow. A new canal would also extend from the Great Western Canal approximately 7 miles to lava fields which lie northwest of Shelley.

Your current plans include provisions for a rotary-type fish screen to be installed about 350 feet below the canal intake. A 36-inch concrete outlet pipe would be located immediately upstream from the fish screen to permit movement of fish back into the river at a point downstream from the diversion dam. This outlet would be about 1,200 feet in length. Average flows which could be diverted from Snake River for ground water recharge purposes would be about 203,000 acre-feet per year. In some years, when extremely high runoff occurs, as much as 608,000 acre-feet per year could be diverted. No water would be available for recharge in dry years.

## Fish

The fishery of Snake River north of Idaho Falls to the river's confluence with Henrys Fork Snake River has been adversely affected by man's activities. Low power and diversion dams have restricted the movement of fish, and the ponded areas created have promoted increases in nongame-fish populations. However, the stream still receives moderate fishermen use and large cutthroat and rainbow trout are caught. Whitefish are taken during the late fall season. The Idaho Department of Fish and Game releases catchable-size rainbow trout throughout this reach annually. Year-round fishing is permitted. Boating is particularly popular in this portion of Snake River.

In general, diversions of surplus flows and flood waters through Great Western Canal would stabilize downstream flows to the benefit of fish and fishing. However, complete elimination of flood and surplus flows would adversely affect spawning activities of game fish. High water permits fish to pass over obstacles which ordinarily cannot be surmounted and enables them to reach preferred spawning areas. Flows adequate to permit upstream migrating fish to reach spawning areas downstream from the diversion dam should be provided during the spring season. Some preferred spawning areas may be underwater only during high-water periods in the spring, and reduced flows during that period could render these areas unusable for spawning. Certain sections of the river are receiving increasing amounts of commercial pollutants during the winter season. These pollutants may become harmful to fish if they are not diluted and carried away by spring flows. The amount of flow needed for the above reasons, however, has not yet been determined.

Fish would tend to concentrate in the river below the existing diversion dam and downstream from the proposed bypass outlet where they would be attracted by flows from the pipe. Fish could not return to the diversion canal through the pipe because of high-water velocities. Fish-passage facilities and sufficient attraction water may be needed to enable fish to pass over the diversion dam. Further study will be needed to determine whether fish facilities will be required.

It is possible that introduction of water into the Idaho Falls recharge area would raise the water table and increase flows in spring areas downstream. Hagerman National Fish Hatchery and the Idaho Department of Fish and Game Hatchery, both near the Thousand Springs area, might be benefited if flows which are used to operate these hatcheries are increased as a result of the project. American Falls Fish Hatchery and McTucker Springs near American Falls Reservoir, used by Idaho Department of Fish and Game to rear trout, might also be benefited in the same manner. Increased spring flows, however, would be beneficial only if the water quality is not impaired.

Wildlife

Good waterfowl and fur-animal habitat are available along the river section adjacent to the diversion inlet. Dense vegetation on islands and along sections of the riverbank provide food and cover for wildlife. Mallards, gadwalls, blue-winged teal, cinnamon teal, green-winged teal, American widgeons, pintails, and wood ducks nest along the river. Nesting use is light, however, because of more desirable habitat upstream and in wildlife management areas near Roberts, Idaho. The river is valuable as a resting area for a variety of waterfowl during fall migration. Islands and shore zones are used by muskrats and minks. Pheasants and mourning doves inhabit adjacent farm and riparian lands.

Diversion of spring runoff could adversely affect downstream wildlife habitat by reducing flows which ordinarily replenish valuable wetlands. Nesting sites for waterfowl and food for both waterfowl and fur animals could be destroyed. The valuable wildlife habitat downstream from Blackfoot, Idaho, particularly in that section of Snake River known as the Fort Hall Bottoms, could be seriously damaged. It is important that these areas be maintained in their present state.

The recharge canal in the Idaho Falls area would terminate in lava fields and these areas would probably be of no significant value to wildlife if water were held for only brief periods. If water stands for significant periods migrating waterfowl would be benefited. Cottontails inhabit the lava fields west of Idaho Falls and are hunted intensively. Introduction of surplus flows into the lava fields during the season when rabbit litters are present could markedly reduce the population. If recharge waters were channeled directly to highly permeable areas and to sections containing injection wells, rather than the planned general flooding of low-lying areas, losses to the cottontail rabbit population would be reduced.

We appreciate the opportunity to work with you on this project. When additional plans and information become available, we would appreciate receiving them so that our investigation may continue concurrently with yours.

/s/ Richard E. Griffith

Richard E. Griffith
Acting Regional Director

STATE OF IDAHO

Robert E. Smylie
Governor

DEPARTMENT OF FISH AND GAME

October 10, 1961

Mr. Paul T. Quick, Regional Director
Bureau of Sport Fisheries and Wildlife
P. O. Box 3737
Portland 8, Oregon

Dear Mr. Quick:

This will acknowledge receipt of draft copies of your report concerning effects the Snake Plain Recharge project, Idaho Falls Recharge Area, Idaho, would have on fish and wildlife.

We concur with your report, with the exception that the need for fish passage facilities around the diversion dam is questioned. Possibly further study is needed in this respect.

During follow up, detailed studies, additional attention should be given to the following items: 1. maintenance of stable stream flows below the diversion dam in the river channel; 2. the possibility of changed water quality with unknown results on fish and wildlife should this introduced water emerge in springs which presently have important fish and wildlife values; 3. should the recharge flooding area present any possibility for waterfowl use development consideration could be given to the incorporation of this as a project enhancement.

We appreciate the opportunity of reviewing your report.

Sincerely yours,

/s/ Ross Leonard

Ross Leonard
Director

cc: Fisheries Management Division
Game Management Division

GENERAL LOCATION MAP NOT REPRODUCED

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UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Mines
Region 1

September 26, 1961

P. O. Box 492
Albany, Oregon

Regional Director
Bureau of Reclamation
Boise, Idaho

Dear Sir:

The Snake Plain Recharge project includes the area of the Snake River plain, principally on the north side of the river, from the upper topographic limits down to the Thousand Springs area near Bliss, Idaho. The foothills on the north of the plain form the northern boundary.

Three recharge areas have been selected and are shown on the General Map. The St. Anthony recharge area is in T. 7 N., Rs. 38 and 39 E. on the boundary between Madison and Fremont Counties; the Idaho Falls recharge area is in Ts. 1 and 2 N., R. 36 E., Bonneville County; and the Milner-Gooding recharge area is in T. 8 S., R. 19 E., Jerome County.

The project area is covered by Quaternary Snake River basalt and lava flows. With the exception of some old gold placers along the river, no mineral occurrences of value are known in the Snake Plain north of the river and south of the foothills. No mineral deposits are known to occur within the boundaries of the recharge areas as described in the previous paragraph.

The Bureau of Mines believes that the recharge project will not affect mineral resources or the mineral industry.

Sincerely yours,

/s/ Mark L. Wright

Mark L. Wright
Regional Director

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
GROUND WATER BRANCH

# FEASIBILITY OF ARTIFICIAL RECHARGE IN THE SNAKE RIVER BASIN, IDAHO

By

M. J. Mundorff

Prepared in cooperation with the

U. S. Bureau of Reclamation

Boise, Idaho

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FEASIBILITY OF ARTIFICIAL RECHARGE IN THE SNAKE RIVER BASIN, IDAHO

By
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Abstract

The Snake Plain aquifer is an important element in the water resources of the Snake River basin. About 800,000 acre-feet of water is available from each foot of saturated thickness of the aquifer. The coefficient of transmissibility ranges generally from 1 to 60 million gallons a day per foot.

Irrigation began on the Snake River Plain in the 1880's, with water diverted from Snake River and its tributaries. Since that time recharge from irrigation has resulted in a rise in the water table of roughly 60 to 70 feet. Coincidently with the rise in water level, total underflow in the aquifer increased from about 5,200-5,500 c.f.s. to about 9,000 c.f.s. by 1950. The aquifer discharges into the Snake River, chiefly in two reaches, the American Falls Reservoir reach and the Hagerman Valley reach.

Since 1950 far more land has been developed with ground water than with surface water, so that the trend of the water table has been reversed. Declines ranging from 1 to 12 feet between 1950 and 1960 are general over the plain.

With the increasing scarcity of favorable sites for surface storage, and the general downward trend of the water table during the past 8 or 10 years, artificial recharge has become increasingly attractive.

Surplus flood-waters are available in many years from the Snake River, Henrys Fork, and some other streams. The bare, rough, porous basalt is favorable for recharge by water spreading in many places. However, most of the central part of the plain is too high to be reached by any feasible route from the rivers. Thus, favorable areas are restricted generally to a belt of terrain between the alluvial valley of the Snake River, which is farmed, and the higher basalt surfaces to the northwest of the alluvial valley. Much of this land is public domain.

Three areas were studied in some detail. All are underlain by basalt with varying amounts of windblown sand and silt overburden.

The area between Roberts and Plano is near the eastern end of the plain. Large areas of land at a suitable altitude are available. However, the silty and sandy overburden has partially filled crevices and other openings in the basalt, thus reducing the intake capacity.

A second area is a few miles west of Idaho Falls where there are 50 to 75 square miles of bare, very rough basalt at a suitable altitude. At some places silty interbeds underlying the uppermost basalt flows

will cause perched water tables, and may spread the recharged water rather widely before it percolates downward to the main water table. In this same general area recharge might also be accomplished by diversion of water into gravel pits adjacent to the river.

A third area is along the Milner-Gooding Canal between Milner and Shoshone. Considerable areas of rough basalt with little overburden are adjacent to the canal where they could be reached by diversion from the canal. There apparently are no extensive interbeds in this area, although lenses of silt might cause local perching.

The effectiveness of recharge is demonstrated by more than 60 years of recharge from irrigation, amounting to roughly $3\frac{1}{2}$ million acre-feet a year, several times the amount of water available for artificial recharge. Artificial recharge will not reverse the downward trend in the water table, because not enough water is available to offset the increasing demands for irrigation from ground water. However, recharge of a million acre-feet will permit pumpage of 2 million acre-feet additional water (assuming 50 percent consumptive use) without any additional decline in the water table.

## Introduction

The Snake River basin, upstream from Bliss, Idaho (fig. 1) includes an area of nearly 36,000 square miles of which about 29,000 square miles is in southeastern Idaho. The population of the area within Idaho is about 275,000, which is about 41 percent of the population of the State. Nearly 2 million acres or about two-thirds of the total irrigated acreage in the State is in the area; also, most industry is based on agriculture, and as a result the economy of the area is closely related to irrigation.

Most of the more easily developed sources of surface water are fully utilized, and development of additional supplies are possible only by means of expensive storage facilities. As surface-water supplies have become more difficult to obtain, use of ground water has increased greatly. The acreage irrigated with ground water has increased from less than 100,000 acres in 1945 to more than 600,000 acres in 1960.

The two largest components of outflow from the basin are ground-water discharge from the Snake Plain aquifer between Twin Falls and Bliss, averaging about 4,700,000 acre-feet per year, and flood flows in the Snake River averaging perhaps 750,000 acre-feet per year. With rapidly increasing development of ground water and the consequent decline in the water table, and with surface-storage sites becoming more costly, underground storage by means of artificial recharge becomes increasingly attractive.

Artificial recharge may be defined as a planned addition of water to an aquifer to increase the supply of ground water in storage so that, (1) more water can be withdrawn at some future date than otherwise would have been available or (2) the same amount of water can be withdrawn with less pumping lift. To be effective, recharge must be with water that otherwise would not have reached the aquifer, or that would have reached it at some other place, where the recharge would have been less advantageous. Although recharge incidental to irrigation with surface water diverted to an area may be very beneficial to the ground-water supply, such recharge generally is not regarded as artificial recharge because the primary objective is to raise crops, rather than to build up the water table. This type of incidental recharge has increased the ground-water supply of the Snake River basin very greatly during the past 80 years.

## Purpose and scope of investigation

The investigation was undertaken by the U. S. Geological Survey at the request of the U. S. Bureau of Reclamation and is a part of their continuing study and appraisal of the water resources and potential for irrigation in the Snake River basin. The investigation by the Geological Survey included study of geology and ground-water hydrology as related to possibilities for artificial recharge in the Snake River basin east of Bliss, and especially to possible artificial recharge of the Snake Plain aquifer. This study is an offshoot of an earlier investigation, by the Geological Survey, in cooperation with the Bureau of Reclamation, which culminated in a report on ground water in the Snake River basin (Mundorff and others, 1960).

The specific objectives of this investigation were to identify areas and aquifers that might effectively be recharged, to describe the geologic and hydrologic features that would control recharge in the Snake River basin in general, and at the potential recharge sites in particular, and to evaluate the effects of artificial recharging on the hydrologic regimen of the basin.

The author was assisted in the field by Chabot Kilburn, R. C. Luscombe, and Sheldon Cordes. Field work began in July 1959, and was completed in July 1961. Field work included collection of pertinent data on wells, collection of sand and silt samples for laboratory analysis, and geologic mapping. Four test holes were drilled to provide stratigraphic and ground-water data. Recharge experiments were conducted at three locations by the Bureau of Reclamation during the period April-July 1961. Technical assistance was given by the Geological Survey, and the results of the experiments are evaluated in this report.

A large amount of data collected in previous investigations was used in the study, and records of irrigation districts and canal companies were also utilized.

## Previous investigations

Although many persons have commented on the possibilities of artificial recharge in the Snake River basin, no specific study had previously been made. However, a number of ground-water reports on the area provided information which was utilized in preparation of this report.

The most important previous studies in the area were those by Stearns, Crandall, and Steward (1938); Stearns, Bryan, and Crandall (1939); Nace, Stewart, and Walton (1959); and Mundorff, Crosthwaite, and Kilburn (1960). The last cited report contains a complete list of investigations and reports on ground water in the Snake River basin through 1959.

## Acknowledgments

Well owners, drillers, and pump companies gave information on wells and water levels. Data were obtained from the files of the U.S. Bureau of Reclamation, the Idaho Department of Reclamation, and irrigation districts and canal companies. Their cooperation is gratefully acknowledged.

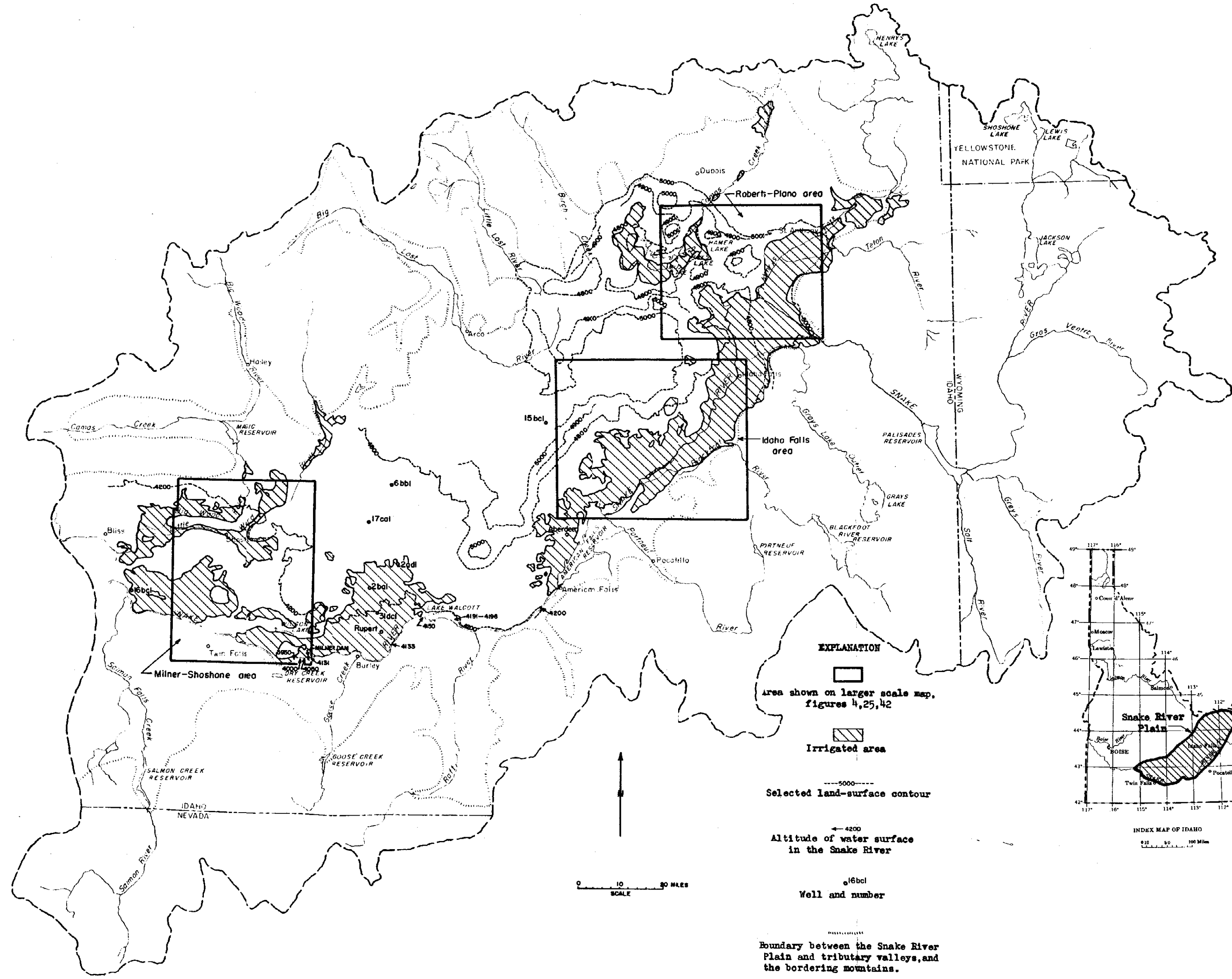


Figure 1.—Index map and map of Snake River basin showing irrigated areas and selected land-surface contours.

## Well-numbering system

The well-numbering system used in Idaho by the Geological Survey indicates the locations of wells within the official rectangular subdivisions of the public lands, with reference to the Boise base line and meridian. The first two segments of a number designate the township and range. The third segment gives the section number, followed by two letters and a numeral, which indicate the quarter section, the 40-acre tract, and the serial number of the well within the tract. Quarter sections are lettered a, b, c, and d in counterclockwise order, from the northeast quarter of each section (fig. 2). Within the quarter sections 40-acre tracts are lettered in the same manner. Well 8S-16E-12bc1 is in the SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 12, T. 8 S., R. 16 E. and is the well first visited in that tract.

## Physical setting

The Snake River basin upstream from Bliss (hereafter referred to as the Snake River basin) consists of the broad central Snake River Plain, and the flanking mountain ranges (figs. 1 and 3).

The Snake River Plain averages nearly 60 miles in width and extends from Bliss northeastward approximately to Ashton, a distance of about 200 miles. The surface of the plain slopes southwestward, from an altitude of more than 6,000 feet north of Ashton, to about 3,200 feet near Bliss. The plain is underlain by a thick sequence of basaltic lava flows and sedimentary interbeds. The surface of the lava flows appears monotonously flat from a distant view but closer observation reveals a variety of land forms and a diversity of geologic features. Broad swells and domes mark some centers of volcanism; craters and cinders, at places alined along great rift zones mark others. Some of the earlier lava flows are covered with a mantle of windblown sand and silt, and in some depressions sedimentary deposits accumulated in playas. The more recent flows are virtually bare and the ropy pahoehoe lava forms flat table- and ramp-like surfaces extending for hundreds of yards. At other places the rough blocky aa forms an exceedingly jumbled and jagged mass. Large lava caves and tubes are found at a few places, and pressure ridges and collapsed lava tubes are common features. One striking feature of the surface of some lava flows are the millions of small round pits commonly 5 to 10 feet in diameter that dot the surface in some areas, and appear from a distance like the surface of a fine textured synthetic sponge. The pressure ridges, collapsed tubes, and pits are all greatly fractured, especially around their peripheries, and many of the fractures gape widely.

Bordering the Snake River Plain on its northwestern and southeastern flanks are a series of subparallel mountain ranges and intervening valleys. The mountain ranges on the northwest flank of the plain rise to altitudes of 11,000 to 12,000 feet; those on the southeast to altitudes of 7,000 to 10,000 feet. The rocks in the mountains are chiefly older consolidated rocks including granite, quartzite, limestone, shale, sandstone, and silicic and basaltic rocks. In general these have been folded and faulted into a series of northwestward trending ranges with intervening structural valleys. The surficial expression of these structures terminates abruptly at the margin of the Snake River Plain which crosses them at approximately a right angle. The older rocks were faulted and warped downward to form a basin in which the basalt flows and associated sedimentary beds of the Snake River Plain accumulated. The thickness of the fill in this broad basin beneath the Snake River Plain is not known; geophysical evidence suggests that the basin is more than 5,000 feet deep. No wells more than a mile or two from the margin of the plain have penetrated deeply enough to reach the underlying bedrock. The deepest well which is in Idaho Falls, is 1910 feet deep.

The structural valleys between the mountain ranges flanking the plain are broad, alluvial filled basins which merge with the Snake River Plain at its margin. Many of these basins are as broad at their heads as at the mouth, and the streams draining them obviously have had little or no role in shaping the valleys. The fill in these valleys consists of alluvial-fan deposits, stream alluvium, basalt, and lake beds.

## Climate and agricultural development

Precipitation on the plain and in the bordering valleys is generally less than 10 inches annually, thus irrigation is required for crops. Limited forage is available for sheep and cattle on the nonfarmed lowlands but this generally lasts only for a short time in the spring. Some bench lands receive 10 to 15 inches of precipitation annually, sufficient for raising wheat, or moderately good pasture. Mountain areas receive up to an average of 50 inches of precipitation, and are used for grazing in the summer months. Much of the precipitation in the mountains occurs as snow.

The length of growing season varies with altitude and other factors, and ranges from less than 60 days in high valleys to more than 120 days at the western end of the plain.

The economy of the entire area is based largely upon irrigation agriculture. Not only do irrigated crops make up the major part of the crops raised, but also stock raising depends to a considerable extent upon hay and grain raised on irrigated farms, and the irrigated fields are used for winter pasture.

A great deal of the industry also is based on irrigation agriculture. Important industries include sugar manufacturing, potato and vegetable processing, meat packing, processing of dairy products and milling of grain. Thus, an adequate water supply for irrigation is of primary importance to the economy of the area.

The basin has far more arable land than can be irrigated even if the entire potential supply could be completely utilized.

## Hydrology of the basin

There are marked contrasts in the water supply of different parts of the basin. The mountain ranges and high uplands have an excess of

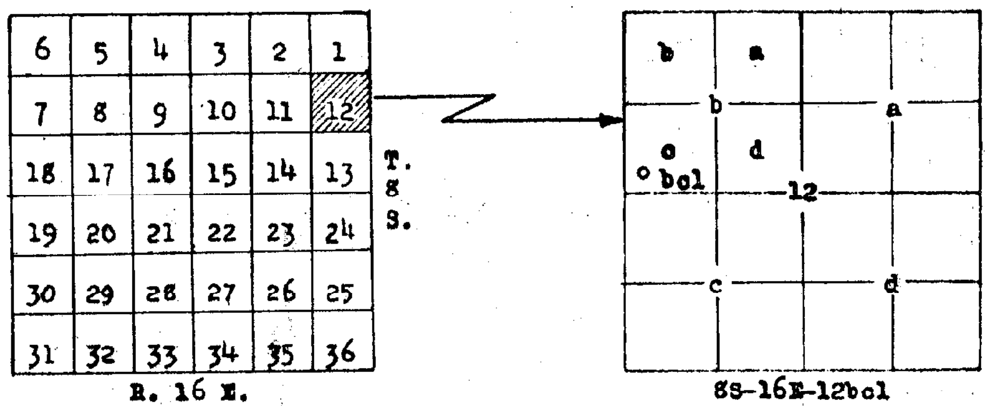


Figure 2.—Sketch of well-numbering system.

water. Precipitation, largely as snowfall, ranges up to 50 inches, much more than evaporates or is used by the native vegetation. The Snake River Plain and tributary valleys receive only 6 to 10 inches of precipitation annually, insufficient for most crops, and water must be supplied by irrigation, either with surface water that enters the plain and valleys from the mountains, or by ground water.

The Snake River which flows along the south margin of the plain is the trunk stream of the basin. Its flow is maintained by perennial streams, chiefly from the east and south. Most streams from the north do not reach the Snake River, their entire discharge is lost a short distance from the mouths of the valleys at the margin of the Snake River Plain.

The Snake River receives large ground-water inflows in two reaches. The first is in the reach from American Falls dam upstream to about the mouth of the Blackfoot River (American Falls Reservoir reach). Inflow in this reach totaled about 1,900,000 acre-feet in 1960. Water from American Falls reservoir, above the dam, is diverted through downstream canals for irrigation. The second reach is below Milner dam, some 60 miles southwest of American Falls dam. Ground-water inflow below Milner dam, largely between Twin Falls and Bliss (Hagerman Valley reach) averages about 4,700,000 acre-feet a year from the north side of the Snake River (discharge from the Snake Plain aquifer) and about 700,000 acre-feet a year from the south side of the river. Because the river is in a deep canyon below Milner dam, little water is diverted from Snake River below that point. From the standpoint of irrigation, the water is largely wasted.

Surface storage facilities upstream have been developed to the point that in less than one-half of the years is it necessary to spill water at Milner, except in minor amounts for fish and prior water-power rights. Development of additional storage, either surface or underground, that would permit irrigation of additional lands, would be of direct benefit to the economy of the area.

## Hydrology of the Snake River Plain

The hydrology of Snake River Plain is summarized in this section to serve as a basis for evaluating recharge possibilities and effects. A more complete description of the hydrology can be found in the report by Mundorff and others (1960).

The limit of the Snake River Plain along its northwest flank is reasonably well defined (figs. 1 and 3). Except where tributary valleys enter the plain, the lava terminates abruptly against the mountain slopes formed on the older rocks. At the mouths of some of the tributary valleys, as at Big and Little Lost Rivers, and Birch Creek, the lavas extend a short distance up the valleys. The boundary of the plain along its southeast flank is less definite. Sedimentary materials were deposited in wide basins formed by damming of Snake River by lava flows, and extend for considerable distances up the tributary valleys. The sedimentary deposits are commonly interbedded with basalt. The southeast boundary of the plain probably can be defined most conveniently by extension across each valley from headland to headland at the northwest end of the intervening mountain ranges.

The part of the Snake River Plain of primary concern in this report is that part underlain by the Snake Plain aquifer. The Snake Plain aquifer is defined as the series of basalt lava flows and intercalated pyroclastic and sedimentary materials that underlie the Snake River Plain extending eastward from Bliss and Hagerman Valley approximately to Ashton and the Big Bend Ridge (fig. 3).

A basalt lava flow generally is fine-grained or glassy and dense at its base. Toward the center of a flow, where the lava cooled more slowly and remained fluid longer, the basalt is coarser grained. Because the top of a flow generally crusted over rather quickly and was subject to pressure from the still fluid lava beneath, it broke into blocks. Thus, the surface of many lava flows is highly irregular, rough, and broken. At places fluid lava drained from the chilled and solidified walls and top leaving lava tubes, many of which collapsed in a jumbled mass. At other places renewed or increased pressure from the fluid lava beneath caused the crust to bulge up and break into pressure ridges leaving gaping cracks at their tops or sides.

Lava poured out over the irregular surface of an earlier flow only partly filled the irregularities, leaving voids between the earlier and later flows. The zones of voids between the top and bottom surfaces of successive flows, commonly termed interflow zones, are the important water-bearing and water-yielding horizons of the Snake Plain aquifer. Pyroclastic volcanic material such as volcanic bombs, clinkers, cinders, and ash frequently were ejected between flows. Where this material is coarse-grained and porous, it adds to the permeability and porosity of the interflow zones.

Lava flows generally have shrinkage joints, developed while cooling, more or less at right angles to the flow surface. These joints are important avenues for movement of water from one flow to another at some places, but are relatively unimportant in the lateral transmission of water. The inability of water to move freely between superimposed water-bearing zones is demonstrated by the commonly observed slight but significant differences in water levels in successive zones.

A single flow overlain by a sedimentary deposit rarely is a good aquifer because most of the openings and interstices at and near its top are filled with sedimentary materials. If these materials are coarse sand and gravel, or cinders, the unit will transmit water freely, but filled openings transmit far less water than ones that are not filled. If the capping and filling material is silt or clay, little or no water will be transmitted.

The Snake Plain aquifer comprises a tremendous hydraulic system serving both as a vast storage reservoir and as a ground-water conduit. The storage capacity of the aquifer is very large. The specific yield probably is on the order of 10 percent and the total porosity may be 15 to 20 percent. Assuming a specific yield of 10 percent, each foot of saturated thickness of the entire 12,000 to 13,000 square miles of the aquifer would yield about 800,000 acre-feet of water. Conversely, each rise of one foot over the entire area of the aquifer would represent a tain in storage of about 800,000 acre-feet.

The ability of the aquifer to transmit water is great. The coefficient of transmissibility generally ranges from 1 to 60 million g.p.d. (gallons per day) per foot, and probably averages 10 million g.p.d. per foot.

Sources of recharge to the aquifer, in order of importance, are: (1) percolation from irrigation diversions, (2) seepage from streams entering or crossing the plain, (3) underflow from tributary basins, and (4) precipitation on the plain. The report by Mundorff and others (1960) included a quantitative analysis of the hydraulic system comprised by the Snake Plain aquifer. Recharge was summarized in that report (p. 177) and is presented in a modified version of their table as follows:

| Source, or segment of Snake River Plain where recharge occurs | Annual recharge (acre-feet) | Average flow (c.f.s.) |
|---|---|---|
| Precipitation on the plain | 500,000 | 700 |
| Tributary basins along north flank | 1,000,000 | 1,400 |
| Upper Snake River valley, above Firth | 2,500,000 | 3,400 |
| Snake River valley, Firth to Blackfoot | 600,000 | 800 |
| Snake River valley, Blackfoot to Neeley | 360,000 | 500 |
| Snake River valley, Neeley to Milner | 400,000 | 600 |
| Snake River valley, Milner to Bliss | 1,200,000 | 1,700 |
| Average annual recharge (rounded) | 6,500,000 | 9,000 |

Discharge from the aquifer is into the Snake River and is chiefly in two areas; in the American Falls Reservoir reach, between the mouth of the Blackfoot River and American Falls (between the Blackfoot and Neeley gaging station), and in the Hagerman Valley reach between Twin Falls and Bliss. In the first reach the average discharge from the aquifer is about 2,600 c.f.s., of which about 500 c.f.s. is recharged within the section, making the net loss from the aquifer in the reach about 2,100 c.f.s. Inflow in the reach is stored in American Falls Reservoir and diverted downstream for irrigation.

Discharge in the second area is chiefly between Twin Falls and Bliss, although there are a few small springs between Milner Dam and Twin Falls, where the aquifer terminates at the canyon of the Snake River. Discharge from the aquifer (north side of river) averages about 6,500 c.f.s. Ground-water inflow in this same reach from the south side of the river averages about 1,000 c.f.s. for a total ground-water inflow in the reach of about 7,500 c.f.s. Surface inflow, about equally divided between streamflow, chiefly the Big Wood (Malad) River, and surface waste from irrigation averages about 700 c.f.s. additional so that the total gain in the reach, as measured by gaging stations below Milner Dam and at King Hill, averages nearly 8,200 c.f.s. The combined discharge from the aquifer in the Blackfoot-American Falls and the Twin Falls-Bliss reach is about 9,000 c.f.s. (rounded).

The quantitative analysis was used by Mundorff and others (1960, fig. 22) to construct a quantitative flow net, which is reproduced as figure 3 in this report. Areas and amounts of recharge and discharge and direction and amount of underflow are shown by flow lines representing underflow of 200 c.f.s. each. Because of lateral and vertical variations in permeability the flow lines do not everywhere cross the contour lines at right angles, as they theoretically would if the aquifer were completely isotropic.

The flow net was used to construct a map showing the transmissibility of the aquifer (Mundorff and others, fig. 55). Both these maps are essential to evaluation of the effects of recharge operations.

The flow net (fig. 3) represents the status of the aquifer approximately as it was in 1959. However, although the aquifer responds rather slowly, it is not static but is continually changing in response to changes of recharge and discharge. Between 1900 and about 1950, diversions for irrigation greatly increased recharge and the underflow, and raised the water table more than 100 feet in some places. The effects of recharge from irrigation diversions are described in detail in another section of the report.

## Ground-water use and effects of withdrawals

Ground-water withdrawals for irrigation began to be quantitatively important after World War II, in 1945 or 1946; and sometime between 1950 and 1955 the amount of acreage added each year through irrigation with ground water began to exceed the acreage added through irrigation with surface water. The increase in ground-water withdrawals is shown graphically in figure 4. Estimated ground-water use in the Snake River basin in 1960 is shown in table 1.

A considerable part of the water pumped percolates back into the ground and returns to the aquifer. The proportions of the water that are consumed or are returned to the aquifer depend upon the method of irrigation, character of the soil, type of crop, and other factors. The amounts shown in the table are estimates only, but are believed to be approximately correct. According to the table, about one-half of all the water pumped is consumed by crops or is evaporated and one-half returns to the aquifer. Thus aquifer depletion is approximately one-half of the amount of ground-water withdrawn.

Changes in ground-water levels are caused by changes in recharge or discharge. Average amounts of recharge were shown in the table on page 7. The amount of recharge depends to a considerable extent upon diversions to irrigated lands. Because of large storage reservoirs, more water is used in the basin in some dry years than in some wet years.

DUMMY SHEET FOR

FIGURE 3 - Contours on the Water Table and Flow Net of the Snake Plain Aquifer (See Figure A following page 17 of USBR report)

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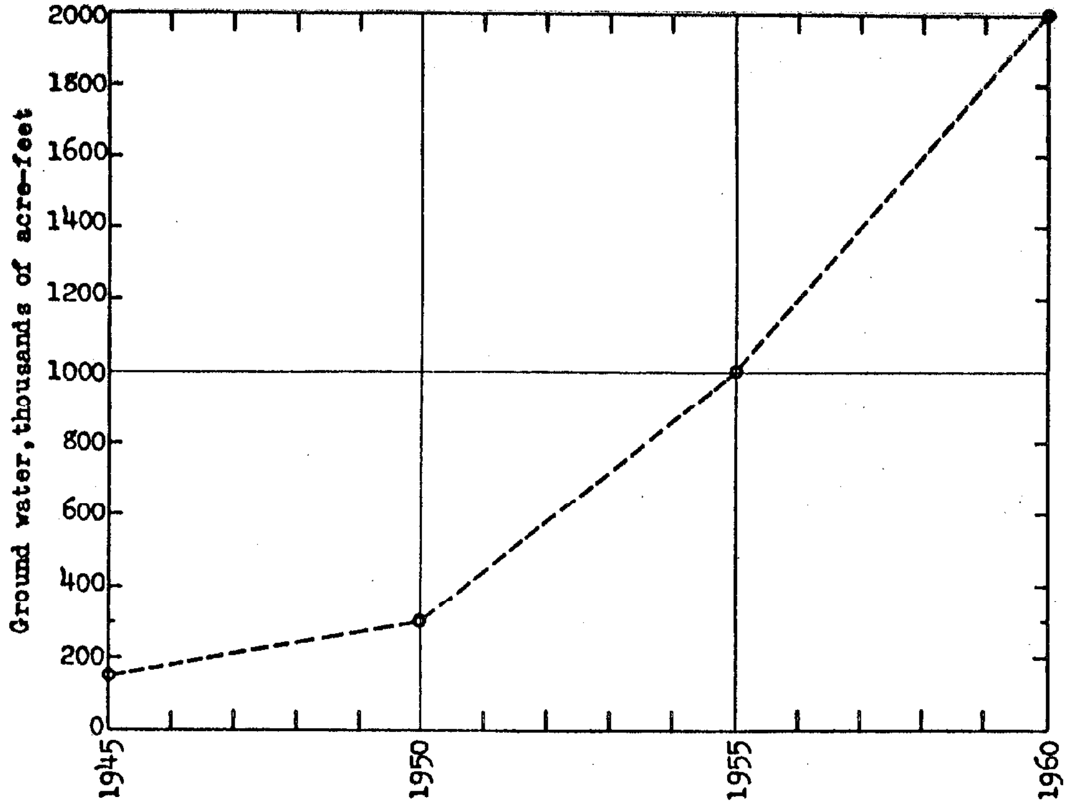


Figure 4.--Estimated ground-water withdrawals in the Snake River basin, 1945-60.

Table 1.--Ground-water use in eastern Snake River basin, Idaho

| Area or Basin | 1960 Acreage | 1960 Amount of water (acre-foot) Pumped | 1960 Amount of water (acre-foot) Consumed | 1961 Acreage |
|---|---|---|---|---|
| **Northern tributary basins:** | | | | |
| Big Wood-Silver Creek | 10,000 | 35,000 | 16,000 | 12,000 |
| Big Lost River Valley | 12,000 | 50,000 | 20,000 | 15,000 |
| Little Lost River Valley | 9,000 | 40,000 | 15,000 | 9,000 |
| | 31,000 | 125,000 | 51,000 | 36,000 |
| **Southeastern tributary basins and areas:** | | | | |
| Goose Creek-Dry Creek | 90,000 | 250,000 | 150,000 | 118,000 |
| Raft River | 38,000 | 127,000 | 65,000 | 40,000 |
| Twin Falls-Salmon Falls | 11,000 | 35,000 | 18,000 | 17,000 |
| | 139,000 | 412,000 | 233,000 | 175,000 |
| **Snake River Plain:** | | | | |
| St. Anthony-Rexburg-Ririe | 15,000 | 50,000 | 22,000 | 20,000 |
| Mud Lake Basin | 86,000 | 300,000 | 140,000 | 90,000 |
| Roberts-Idaho Falls area | 40,000 | 130,000 | 65,000 | 50,000 |
| Blackfoot-Aberdeen | 110,000 | 330,000 | 170,000 | 120,000 |
| Pocatello area | 7,500 | 25,000 | 12,000 | 8,500 |
| American Falls area | 21,000 | 65,000 | 35,000 | 26,000 |
| Michaud Project (USBR) | 3,500 | 7,500 | 5,000 | 3,500 |
| Minidoka Project (USBR) | 61,000 | 205,000 | 100,000 | 62,000 |
| Minidoka-Hazelton area | 80,000 | 240,000 | 125,000 | 90,000 |
| Jerome-Wendell area | 21,000 | 65,000 | 35,000 | 30,000 |
| Shoshone-Gooding area | 5,000 | 15,000 | 8,000 | 8,000 |
| | 450,000 | 1,432,500 | 717,000 | 508,000 |
| Total | 622,000 | 1,969,500 | 1,001,000 | 719,000 |
| (rounded) | 620,000 | 2,000,000 | 1,000,000 | 720,000 |

Thus, the index to recharge is not precipitation on the basin, but the quantity of water retained in the basin. For the period 1941-60 the amount of inflow from every major source east of Bliss was totaled for each year, and the surface outflow at the gage below Milner Dam was subtracted. A correction was made for changes in storage in American Falls reservoir. The resulting quantity is the amount of water entering or added to the basin during the year, and is an index of ground-water recharge. The position and trend of the water table is not determined solely by the current year; recharge during previous years has some influence. In order to make allowances for earlier years in the recharge index, 1/2 the water retained in the basin during the current year, 1/3 of the previous year and 1/6 of the second preceding year were totaled for use as the index for the current year. The "recharge index" obtained in this way for the period 1950-60 is plotted in figure 5. Also shown in this figure are hydrographs of wells 2N-31E-35dc1, 8S-24E-31dc1, and 5S-15E-35dc1. Water levels in the three wells are representative of water levels measured in a large number of observation wells in the central and western parts of the Snake River Plain. The recharge index rose in 1950-53, held about steady in 1954, declined in 1955 and rose fairly steadily the remaining five years. The water levels shown by the hydrograph of well 8S-24E-31dc1 (5 miles north of Rupert) rose with the recharge index through 1953, declined in 1954 and 1955, and continued declining through 1960, even though the recharge index was rising. The decline in the water table in this area since 1953 obviously is related to the great increase in ground-water pumping in the Minidoka-Hazelton area which began about 1950 and became quantitatively significant by 1952.

The fluctuations in wells 2N-31E-35dc1 and 5S-15E-35dc1 show about the same influences and trends, except that the wells are considerably more distant from areas of major ground-water pumpage, and pumpage in areas nearest each of these wells did not become quantitatively significant until 1957 or 1958.

Ground-water development in the Snake River Plain presumably will continue. Because of the large amount of water in storage and the very high coefficient of transmissibility the rate of decline has been, and probably will continue to be low, probably averaging less than 1 foot per year. However, the decline will continue for many years.

## Factors affecting feasibility of artificial recharge in the Snake River basin

Among the many factors which affect the feasibility of artificial recharge in the Snake River basin, and limit the selection of suitable sites, a few are of primary importance. These are the availability of water suitable for recharging, a suitable topographic situation, satisfactory transportation route from source to site, and a suitable site with adequate absorptive capacity of the materials underlying the site. Large parts of the Snake River basin and the plain are eliminated from consideration because one or more of the above factors are unfavorable.

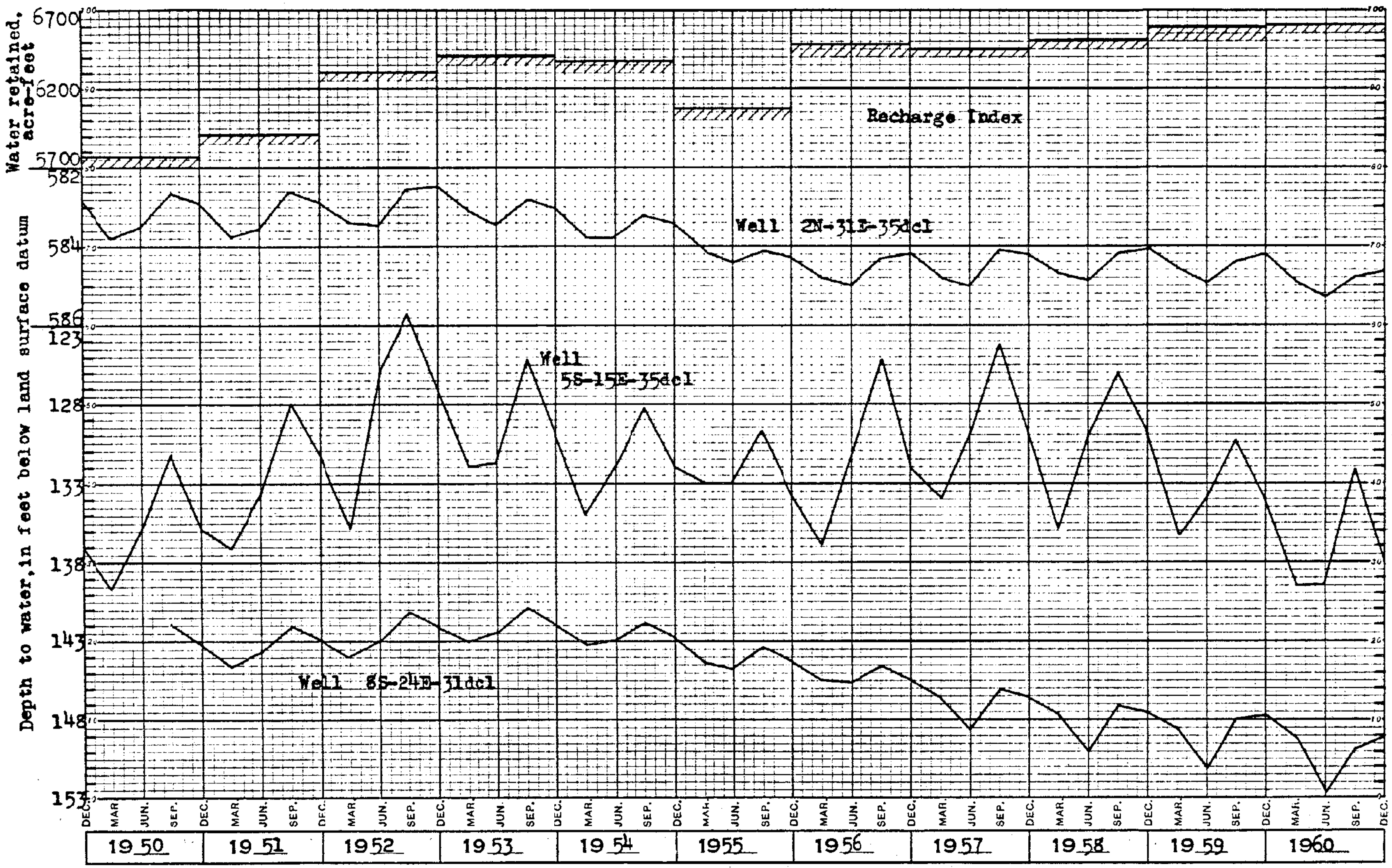


Figure 5.--Water level in three wells compared with the "recharge index", 1950-60.

Another consideration further narrows the selection of suitable sites. In the Snake Plain aquifer the ground-water mound spreads rather rapidly; at some places the water table begins rising at points as distant as 25 miles from a recharge area within a few months after recharge begins. Thus water can be stored for periods of several years only if the recharge area is remote from the points of discharge. For this reason the most desirable locations would be at the upgradient (eastern) end of the aquifer. Recharge in that part of the aquifer would raise water levels throughout the aquifer, whereas recharge near the discharge areas (i.e., near American Falls reservoir, or the Twin Falls-Bliss reach) would raise water levels only near the recharge sites, and the rise would be of relatively short duration after recharge ceased.

## Availability of water

Surplus water is available in some years from the Snake River and from Henrys Fork. A study was made by the U. S. Bureau of Reclamation (written communication, 9-6-61) of historical flows past Milner Dam, the last major downstream diversion point, for the 30-year period of water years 1928-57, modified to reflect current operating conditions and storage facilities.

This study showed that in 8 of the 30 years more than 1,000,000 acre-feet of water a year would have been available for recharging, and in 14 years more than 500,000 acre-feet would have been available. In 3 other years more than 150,000 acre-feet would have been available. In 13 years little or no water would have been available.

Proceeding on the principle that the water should be recharged as far upgradient in the aquifer as is feasible, the Bureau of Reclamation concluded that water in an amount exceeding 100,000 acre-feet would have been available from the Henrys Fork at St. Anthony in 12 of the 30 years. In five other years the water available would have exceeded 20,000 acre-feet. In the other 13 years of the study period little or no water would have been available for recharging.

Assuming operation of a 2,000 c.f.s. canal diverting from the Henrys Fork for recharge of surplus water, the amount of water available from Snake River below the mouth of the Henrys Fork was estimated by the Bureau of Reclamation to exceed 250,000 acre-feet in 14 years of the 30-year period. In 2 other years the water available would have exceeded 100,000 acre-feet, and in the other 14 years little or no water would have been available for recharging. The water would have been available in the 6-month period, January through June. Although substantial quantities of water were available for recharge in more than half the years of the base period, these years are not evenly distributed. For example no water would have been available during one 8-year period, and except for about 30,000 acre-feet available in one year, this period would have extended to 12 years. On the other hand substantial flows, 150,000 acre-feet in the lowest year, would have been available each year for recharging during the last 15 years of the base period. The same pattern may not be repeated, but there probably will be periods of several years when no water is available for recharging and equally long intervals when ample water is available. Design of any recharge and recovery system must take into account the erratic time-distribution of surplus streamflows that would be available for recharging.

Surplus water also is available for recharging in some streams tributary to the plain. Some flood water discharges from the Blackfoot, Portneuf, and Big and Little Lost Rivers. Artificial recharge might be of local benefit within these tributary basins, but would not benefit the Snake Plain aquifer for the following reasons. Discharge from the Blackfoot and Portneuf Rivers is caught in American Falls Reservoir. Because sufficient water must be allowed to flow downstream in the Snake River to fill American Falls Reservoir, use of floodflows from the Blackfoot and Portneuf Rivers would reduce the amount of water available at upstream points from the Henrys Fork and Snake River by an equal amount. Big and Little Lost Rivers lose their entire discharge at the margin of the Snake River Plain. Diversion of floodflows for recharge in upstream reaches would reduce recharge at the margins of the plain by an approximately equivalent amount. (There might be slight differences in evaporation losses at the two recharge sites).

Surplus flood water is available in most years from the Big Wood River drainage. Discharge records at the gaging station on Big Wood River (formerly Malad River) southwest of Gooding show annual discharges ranging from 35,000 to 499,000 acre-feet during the period 1938-60. Average annual discharge for the 23 year period was about 185,000 acre-feet. In only two years was the annual discharge less than 75,000 acre-feet, and only in 6 years was it less than 99,000 acre-feet. In 9 years it exceeded 200,000 acre-feet. Surplus water could be diverted from the Big Wood River to recharge areas below Magic Reservoir; or from the tributaries, Silver Creek and Little Wood River, to areas along the margin of the plain.

## Topographic situation

The Snake Plain aquifer is chiefly north of the Snake River and most of the areas suitable for recharging also are north of the river. Because of economic considerations it probably is not feasible to use pumps to raise water to a recharge site higher than the source of the water supply, or to construct long siphons or to use pumps to cross a broad depression to reach a recharge site. If the water to be used for recharging is to be transported by gravity, the potential recharge areas are limited to lands lower in altitude than the highest practicable diversion from Henrys Fork or the Snake River. Henrys Fork enters the Snake River at an altitude of about 4,800 feet (figure 3), and the only practicable way in which to bring water from the Snake River to the plain on the north side of the river system at a higher altitude would be to divert water upstream on the Snake River through a cross canal to Henrys Fork. However, there would be sufficient flow in Henrys Fork, during periods that surplus water was available for recharging, so that a large part of the total could be taken from that river. There are feasible diversion points on Henrys Fork in the vicinity of St. Anthony at altitudes of about or slightly above 5,000 feet. Thus 5,000 feet may be taken as the upper limit of any feasible recharge site.

The central part of the Snake River Plain is higher than the flanks. In the northeastern end of the plain the terrain below 5,000 feet is chiefly adjacent to the Snake River and Henrys Fork, and in the vicinity of Mud Lake and the mouths of Birch Creek and Little Lost River.

Farmed lands generally are not suitable for recharge sites because the soil has too low a permeability for adequate percolation rates. also, it doubtless would not be economically feasible to include more than small incidental areas of arable land. The arable lands in the Snake River Plain are chiefly confined to a very irregular belt adjacent to Snake River on the southeast side of the plain, and irregular areas near the mouths of major tributaries along the north flank of the plain. Thus, areas suitable as sites for artificial recharge in general are bounded on one side by topographic contour lines beyond which it is not practicable to conduct recharge water, and on the other side by arable lands which are neither suitable for, nor available as recharge sites. The one exception are gravel pits adjacent to Snake River in reaches where the river is above the water table.

Water could be taken out of Henrys Fork at an altitude of about 5,000 feet upstream from St. Anthony and conveyed westward and northwestward into a large area north of Hamer and Mud Lake. The canal required would be 30 or 40 miles long.

A closer site which could be served by a canal of the same general alinement lies immediately west of Plano (see figure 11). However a broad sag in the topography would drop the canal about 20 or 30 feet below the 4,900 foot contour. The area above the 4,900-foot contour thus is immediately eliminated. The area below the 4,900-foot contour extends westward for many miles, passing south of Mud Lake. However a topographic depression extends northward from Roberts to Hamer (followed generally by the railroad). Topographic maps are not available for that part of the area, but elevations along the railroad indicate that a canal crossing the depression probably would do so at an altitude of not more than about 4,840 feet, further limiting the recharge area. The site is described in more detail in another section of the report.

The first feasible downstream diversion site below the junction of Henrys Fork and Snake River is south of Roberts at an altitude of about 4,750-55. Although it would be possible to divert from the Snake River near Menan Buttes and carry the water north of Roberts, the added potential recharge areas probably would not be worth the additional construction expense. Diverting at an elevation of about 4,750 south of Roberts, water could be transported to a potential recharge site southwest of Idaho Falls. Another possible recharge site is northwest of Springfield. Water could be brought to this site by constructing a canal from the Idaho Falls site, and water might reach the site at an altitude of around 4,700 feet. Because of a considerable drop in the river at Idaho Falls, and in the reach downstream to Firth, diversion canals downstream from Idaho Falls could reach only a narrow strip adjacent to the Snake River. The Shelley and Springfield sites also are described in more detail in a later section of the report.

Large unused areas underlain by basalt west of Aberdeen and north of Lake Walcott appear to be suitable for recharging. However, as can be seen by study of river- and land-surface altitudes in figure 1, canals to bring water to these areas would be impracticably long and expensive. Several existing irrigation canals divert water to the plain from the reservoir (Lake Milner) above Milner Dam. Diversions are at an elevation of about 4,130 feet. Surplus water could be diverted to areas suitable for recharge through existing canals. Diversion to this part of the plain at altitudes higher than 4,130 feet does not appear to be practicable. There is a difference in altitude of only about 60 feet between Lake Milner and Lake Walcott which is 29 miles, airline, to the northeast. Diversions from Lake Walcott would not reach any appreciably different or better recharge area. The recharge area north of Lake Milner is described in more detail in a later section of the report.

Below Milner Dam the Snake River flows in a deep canyon and diversion of water for recharge downstream from that point is impracticable.

## Water quality and temperature

The chemical quality of water used to recharge an aquifer may affect the feasibility of the recharging operations. This is particularly true where the percentage of dissolved solids is large, or where the recharge water is not chemically compatible with the water in the aquifer.

Because the present recharge to the aquifer is almost entirely from the same sources as the proposed artificial recharge, chemical compatability does not appear to present any problem. Analysis of water from the Henrys Fork, Snake River, and three typical wells are given in table 2.

Differences in temperature probably will have little effect on compatibility of the water. However, water for artificial recharge will be available chiefly in late winter and spring months, and the temperature of the water will be low, at times very little above freezing. Average monthly temperatures of water in the Snake River at the Heise gaging station in water year 1957 were as follows (°F): Oct. 46, Nov. 36, Dec. 33, Jan. 32, Feb. 34, Mar. 35, Apr. 39, May 46, June 53, July 56, Aug. 59, Sept. 56. Temperature data for Henrys Fork are not available, but temperatures probably are nearly the same as for the Snake River. Thus, recharge water generally will be at temperatures between 32 and 40°.

The temperature of the ground water is considerably warmer, averaging about 54°-56°. The chief effect of the lower temperature of the recharged water will be to decrease the coefficient of transmissibility. The coefficient of transmissibility is determined at the prevailing temperature of the water in the aquifer, in this case about 55°. At a temperature of 40° the coefficient would be 79 percent, and at a temperature of 33°, the coefficient would be only 69 percent of the

Table 2.--Chemical analyses of water from 2 rivers and 3 wells.

(Analyses by U. S. Geological Survey. Chemical constituents in parts per million)

| | Henrys Fork near Rexburg | Snake River near Heise 1/ | Well 6N-40E-30bd1 City of Rexburg | Well 1S-32E-23cb1 near Tabor | Well 6S-17E-2ab1 City of Shoshone |
|---|---|---|---|---|---|
| Date of collection | 7-14-59 | - | 8-27-57 | 9-10-54 | 10-30-56 |
| Temperature (°F) | 72 | - | 54 | 55 | 56 |
| Silica ($SiO_2$) | 26 | 10 | 26 | 36 | 33 |
| Iron (Fe) | .23 | - | .04 | - | .00 |
| Calcium (Ca) | 19 | 49 | 53 | 36 | 48 |
| Magnesium (Mg) | 5.8 | 11 | 16 | 12 | 14 |
| Sodium (Na) | 11 | 10 | 8.3 | 23 | 16 |
| Potassium (K) | 2.0 | 1.9 | 2.4 | | 3.2 |
| Bicarbonate ($HCO_3$) | 97 | 162 | 235 | 168 | 220 |
| Sulfate ($SO_4$) | 7.4 | 41 | 10 | 29 | 19 |
| Chloride (Cl) | 5.0 | 10 | 6.5 | 12 | 8.0 |
| Dissolved solids: | | | | | |
| Residue | 168 | 219 | 232 | 229 | 261 |
| Calculated | 126 | | 242 | 234 | 255 |
| Total hardness as $CaCO_3$ | 71 | 168 | 198 | 139 | 177 |
| Specific Conductance (micromhos at 25°C) | 189 | 362 | 394 | 358 | 404 |
| pH | 6.9 | 7.0-7.9 | 7.8 | 8.4 | 8.0 |

1/ At the Heise gaging station, weighted average for water year 1957 (Water Supply Paper 1523, p. 430).

coefficient at 55°. Probably the greatest effect of water temperatures will be in percolation from the surface to the water table. Percolation may be only two-thirds as great when the water is near freezing, as it would be at a temperature of 55° to 60 °. A pond capacity nearly 50 percent larger would be required for the water at 33°F than would be needed for water at 55°F.

## Recharge incidental to irrigation on the Snake River Plain

The hydrologic regimen of the Snake River Plain has been changed very markedly because of irrigation of lands on the plain. The discharge of ground water in the Twin Falls-Bliss reach increased about 2,500 c.f.s., and discharge in the Blackfoot-American Falls reach probably increased about 1,200 to 1,500 c.f.s. because of irrigation. This increase in underflow and in discharge does not represent all the water recharged to the Snake Plain aquifer by irrigation; natural recharge from Henrys Fork and Snake River has been reduced because flooding has virtually been eliminated. Thus, recharge from irrigation probably is more than half the total recharge, perhaps 4,500 to 5,000 c.f.s., about $3\frac{1}{2}$ million acre-feet a year. This is recharge to the Snake Plain aquifer; much additional water is recharged to, and discharged from perched aquifers east of Idaho Falls, and in the Burley-Rupert (Minidoka) area.

The annual recharge to the Snake Plain aquifer from irrigation operations far exceeds the amount that could be added by artificial recharge. Thus, perhaps the best clue to the effects that the proposed artificial recharge would have on the aquifer are the changes already caused in the aquifer by recharge from irrigation. The effects of irrigation on the water table in two areas are described below.

### Aberdeen area

Irrigation diversions to the Snake River Plain upstream from the Aberdeen area began before 1890. According to Simons (1953, p. 60-65) the area irrigated exceeded 250,000 acres in 1900, and 355,000 acres in 1905. Not all the irrigated area listed was in the Snake River Plain, some was in headwaters areas upstream from the plain. Probably about 200,000 acres in 1900, and 300,000 acres in 1905 were in the Snake River Plain. Practically no data are available on actual diversions for irrigation, but the information that is available indicates that diversions were considered to be excessive. Assuming an average diversion of 8 acre-feet per acre, diversions would have been about 1,600,000 acre-feet in 1900 and 2,400,000 acre-feet in 1905. Undoubtedly diversions of that amount of water to lands adjacent to the Snake River had considerable effect on the water table at an early date, and even though much of the irrigated land was many miles upgradient from the Aberdeen area, the water table probably had risen considerably before irrigation of the Aberdeen tract began in about 1910.

Beginning with 1930, fairly complete records of diversions are available. Diversions in the early 1930's averaged about 3,200,000 acre-feet a year, by 1940 were averaging about 3,600,000 acre-feet, and by 1950 were exceeding 3,800,000 acre-feet a year.

In 1960 more than 4,300,000 acre-feet of water was diverted for irrigation of 432,000 acres of land in the Snake River basin above American Falls, excluding the headwaters areas (Eagle, 1960). Probably 75 to 80 percent of the amount diverted percolates into the ground and becomes ground water; however not all this water reached the Snake Plain aquifer, a substantial amount recharged perched aquifers and returned to the Snake River in upstream reaches. Of every 10 acre-feet diverted for irrigation, approximately 3.5 acre-feet is consumed or recharges perched aquifers, 2.5 acre-feet discharges into American Falls Reservoir, and 4 acre-feet continues westward in the aquifer to discharge in the Milner-Bliss reach.

Water diverted for artificial recharge upstream from American Falls will not be consumed by crops (minor amounts may evaporate) and would be recharged directly into the aquifer, or into perched aquifers which would feed into the main aquifer, not into surface streams. Therefore nearly all the water diverted would become recharge and roughly 40 percent of the water recharged by artificial means upgradient from American Falls would return in the American Falls reach, and 60 percent would return in the Milner-Bliss reach. This ratio holds only as a rough general rule. A larger proportion of water recharged in the near vicinity of the American Falls discharge area would obviously return in that reach.

Although discharge of the aquifer in the American Falls reach is related to irrigation on the entire segment of the plain to the northeast, the fluctuation of the water table in the Aberdeen-Springfield area is closely related to diversions of water for irrigation in the immediate area. Diversions to the Aberdeen Canal and hydrographs of 4 wells in the area are shown graphically in figure 7. These curves clearly show that the recharge mound produced by irrigation moves outward in the aquifer. Well 4S-33E-3cb2, within the irrigated area, responds within a few days. Water-level measurements are at too great an interval to fix the exact time required for their response, but approximate travel times can be determined. Well 2S-32E-23bb1, 8 miles from the edge of the irrigated area, responds within 40 to 80 days. Well 1S-30E-15bc1, 19 miles from the margin of the irrigated area responds after 75 to 100 days and well 2N-31E-35dc1 about 22 miles away responds after 90 to 105 days.

A total of 362,000 acre-feet of water was diverted into the Aberdeen Canal during the 1960 irrigation season of about 5½ months. Transmission losses, mostly to ground water, were 38½ percent, or nearly 140,000 acre-feet. Of the 222,000 acre-feet delivered to the farmer, probably about 2 acre-feet per acre, 100,000 acre-feet for 48,500 acres in the project, were consumed, another 10,000 acre-feet was surface waste, leaving about 110,000 acre-feet additional which percolated to the water table. Total recharge to the water table from irrigation thus was about 250,000 acre-feet, for an average rate of about 45,000 acre-feet per month and the maximum rate, during June and July, exceeded

50,000 acre-feet per month. This water was recharged over an area of 4 or 5 townships. The seasonal rise in water levels ranged from about 1 to 12 feet in 18 wells in the irrigated area and averaged nearly $5\frac{1}{2}$ feet.

The rise in water level caused by recharge was 2.3 feet at well 2S-32E-23bb1, 8 miles from the edge of the irrigated area; 1.3 feet 19 miles from the edge of the irrigated area; and 0.9 foot 22 miles from the edge of the irrigated area.

## Minidoka Project area

Diversions of surface water to irrigate an area of about 12 by 15 miles in the Burley-Rupert area (fig. 1) (Minidoka Project) began in about 1908. Diversions exceeded 450,000 acre-feet in 1910 (calendar year), 660,000 in 1915, 730,000 in 1920 and 800,000 in 1930. Diversions for the period 1945-60 are given in the following table:

| Year | Minidoka Canals North Side | Minidoka Canals South Side | Total | Year | Minidoka Canals North Side 1/ | Minidoka Canals South Side | Total |
|---|---|---|---|---|---|---|---|
| 1945 | 432,000 | 319,000 | 751,000 | 1953 | 434,000 | 353,000 | 787,000 |
| 1946 | 438,000 | 331,000 | 769,000 | 1954 | 456,000 | 370,000 | 826,000 |
| 1947 | 451,000 | 347,000 | 798,000 | 1955 | 426,000 | 356,000 | 782,000 |
| 1948 | 432,000 | 356,000 | 788,000 | 1956 | 460,000 | 380,000 | 840,000 |
| 1949 | 439,000 | 352,000 | 791,000 | 1957 | 491,000 | 344,000 | 835,000 |
| 1950 | 435,000 | 371,000 | 806,000 | 1958 | 528,000 | 365,000 | 893,000 |
| 1951 | 464,000 | 358,000 | 822,000 | 1959 | 506,000 | 353,000 | 859,000 |
| 1952 | 469,000 | 386,000 | 855,000 | 1960 | 525,000 | 386,000 | 911,000 |

1/ Includes Minidoka North Side pump canal, 1957-60.

Although diversions have varied from year to year, depending on availability of water and irrigation requirements, there has been no significant increase in diversions since the 1920-30 period. A large part of the surface water diverted percolates downward to the water table and recharges the main aquifer. Shallow aquifers are perched on clay and silt strata in the vicinity of Burley and Rupert and these perched aquifers discharge, in part, into the Snake River within the reach. In their analysis of recharge to and discharge from the Snake Plain aquifer Mundorff and others (1960, p. 174) estimated that the aquifer gained about 400,000 acre-feet a year in the reach of the river between Neeley and Milner. Part of this gain is derived from underflow from the Raft River basin, but a large part, perhaps about 300,000 acre-feet a year is derived from downward percolation of surface water diverted for irrigation. Actual percolation losses are considerably greater, probably in excess of 60 percent of the water diverted, or 450,000 to 500,000 acre-feet a year. The difference between 300,000 and 450,000 to 500,000 represents water returned to the Snake River within the Neeley-Milner reach by perched aquifers. Increased recharge because of irrigation

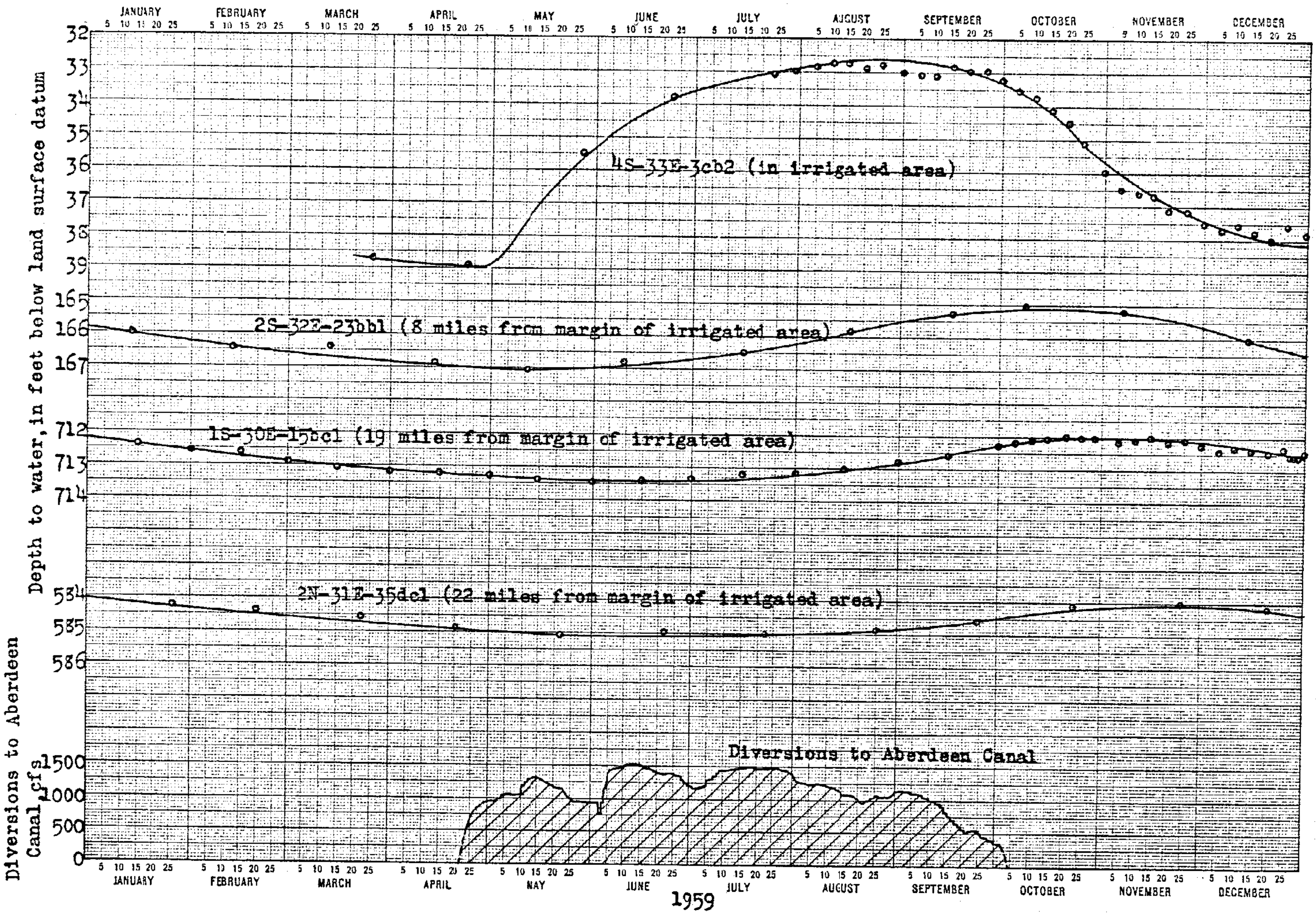


Figure 7.--Diversions to the Aberdeen Canal and hydrographs of four wells.

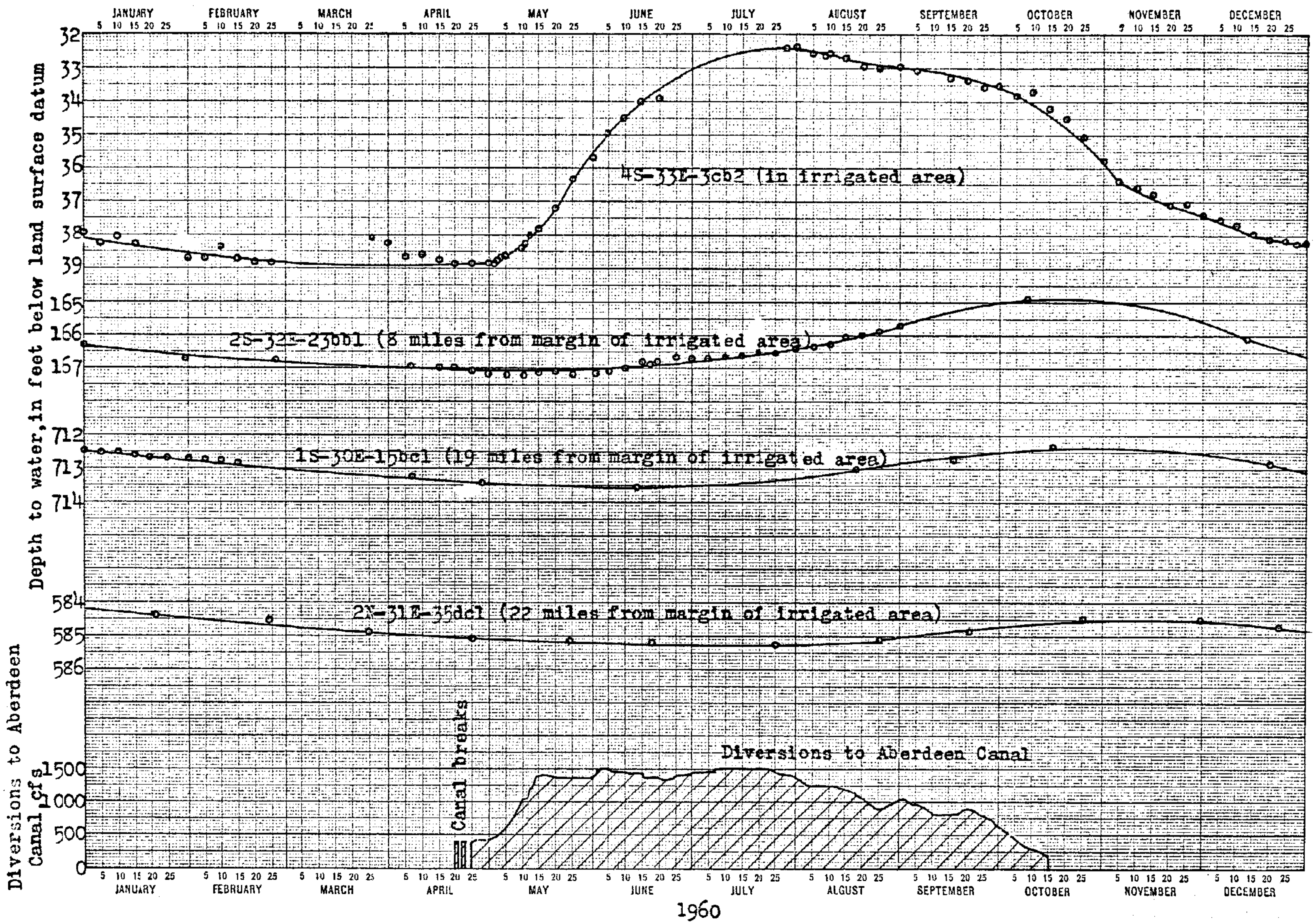


Figure 7.—Diversions to the Aberdeen Canal and hydrographs of four wells.

after 1908 raised the water table considerably. The rise in water level in the few wells for which information is available ranged from about 40 to 195 feet in the Minidoka Project area. (Mundorff and others, 1960, p. 150.) Because irrigation developments in other parts of the Snake River Plain were in progress simultaneously with the Minidoka Project, the effects of the Minidoka Project cannot be isolated. Nevertheless, it is apparent that irrigation in the Minidoka area was an important factor in raising the water table an average estimated amount of 60 to 70 feet throughout that part of the Snake River Plain. Most of the rise occurred before 1920. Occasional measurements of water level in various wells in the area indicate that the water table did not change more than a few feet from the 1920's to 1950. It thus appears that diversion of an average of 750,000 to 800,000 acre-feet of water is just sufficient to maintain the water table about its present position, or stated conversely, diversion of surface water over a period of 40 to 50 years has been sufficiently uniform to stabilize the water table within a relatively narrow range at a level estimated to be some 60 to 70 feet above the preirrigation level.

Since 1950 the greatest change in the hydrologic regimen of the area has been the drilling and use of a large number of wells for irrigation. Estimated ground-water pumpage and consumptive use on the north side of the Snake River in the Minidoka Project area is given in the following table:

| Year | Ground water | | Year | Ground water | |
|---|---|---|---|---|---|
| | Pumped (acre-feet) | Consumed (acre-feet) | | Pumped (acre-feet) | Consumed (acre-feet) |
| 1951 | 50,000 | 25,000 | 1956 | 200,000 | 100,000 |
| 1952 | 75,000 | 38,000 | 1957 | 240,000 | 120,000 |
| 1953 | 100,000 | 50,000 | 1958 | 300,000 | 150,000 |
| 1954 | 135,000 | 68,000 | 1959 | 330,000 | 165,000 |
| 1955 | 160,000 | 80,000 | 1960 | 365,000 | 183,000 |

Irrigation from ground water is north and northwest of the area served with surface water, and is chiefly beyond the limits of the perched aquifers so that most of the water that is not consumed returns to the Snake Plain aquifer.

The effects of recharge from surface-water diversions, as well as the effects of withdrawals of ground water, are shown very clearly by hydrographs of observation wells in the area. The hydrographs of two wells and cumulative departure from average monthly diversion of water to the North Side Minidoka Canal for the period 1951-60 are shown in figure 8. Because ground-water withdrawal was a relatively minor amount for the first few years shown on the graph (1951-53), that part of the graph shows most clearly the effects of surface-water diversions. Well 8S-24E-31dcl is immediately adjacent to the area irrigated with surface water which lies to the south, and also to the area irrigated with ground water which lies to the north. There was little or no lag between diversion of surface water and the change from a downward to an upward trend of the water level in the well. Well 8S-23E-2ba1 is about 6 miles from the area irrigated with surface water, and there is a lag of 3 to $3\frac{1}{2}$ months between diversion of surface water and a rise in the water table. Both wells showed a net rise during the period 1951-53 which is attributed to above average diversions in 1950-52. Diversions were down slightly in 1953, but the water table continued to rise, apparently because of some lag in recharge, perhaps representing water in downward transit from perched aquifers. In 1954 the water level in both wells began a general downward trend upon which is superimposed the annual recharge-discharge cycle. The same trends are shown by more than a dozen other observation wells in the area.

Recharge from irrigation occurs chiefly during the irrigation season (allowing for some lag because of the time required for downward movement to the water table, and some lag in leakage from perched aquifers). Discharge is continuous. If there were no recharge from irrigation, the water table would continue to decline, as shown by the dotted line extending the drawdown cycle for well 8S-24E-31dc1. By drawing a perpendicular line from the highest point shown on the hydrograph (141.6 at the end of September, 1951 for example) to the extended drawdown curve, the rise in the water table caused by irrigation is found to be about 5.0 feet in 1951. Actually, the rise would have been somewhat more, but consumptive use of about 25,000 acre-feet of ground water in the adjoining area reduced the rise. Assuming that consumptive use and return to the river through perched aquifers is relatively constant from year to year on the surface-water project, the relation of these factors to the rise in the water table can be expressed by the equation $S_d - C - G_c = KR$, where $S_d$ is surface diversion in acre-feet, C is the consumptive use, in acre-feet, on the tract irrigated with surface water, $G_c$ is ground water consumed on the ground-water tract, K is acre-feet per foot of rise and R is the total rise in the water table. C and K are unknown but can be determined graphically. If the data from the preceding two tables and the hydrograph are used in this equation and plotted, the data roughly define a straight line passing through the points C = 500,000 at R = 0 (fig. 9). K is the slope of the line and is about 60,000 acre-feet per foot. That is, of the 750,000 to 850,000 acre-feet of surface water diverted to the Minidoka Project each year, roughly 500,000 acre-feet is consumed by crops or is returned to the river by perched aquifers, and the remainder, 250,000 to 350,000 acre-feet is recharged to the Snake Plain aquifer (recharge of 300,000 acre-feet a year was estimated by a different method on page 18).

To sum up, irrigation in the Minidoka Project of some 12 by 15 miles results in an annual recharge of 250,000 to 350,000 acre-feet. This recharge, beginning in 1908 was a major factor, along with irrigation in other parts of the Snake River Plain, in raising the water table perhaps 60 or 70 feet. The position of the water table had stabilized after 10 or 15 years of irrigation so that there was little net change in the water table from the 1920's to 1950. The annual recharge cycle is shown by a number of observation wells in the area for the period 1951-53 when withdrawal of ground water for irrigation was relatively minor. Recharge of 250,000 to 350,000 acre-feet of

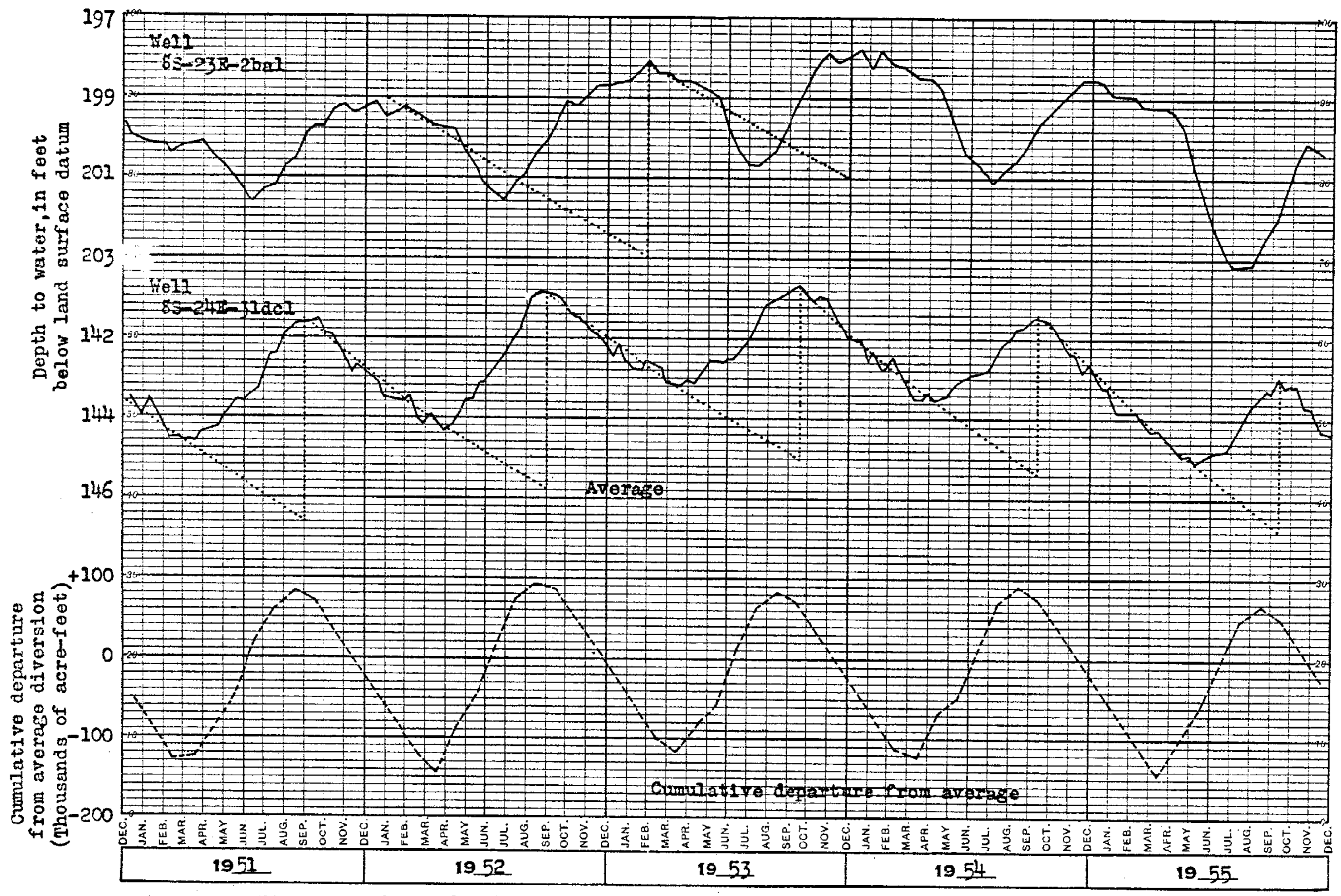


Figure 8.—Water level in two wells compared with cumulative departure from average diversion to Minidoka North Side canal.

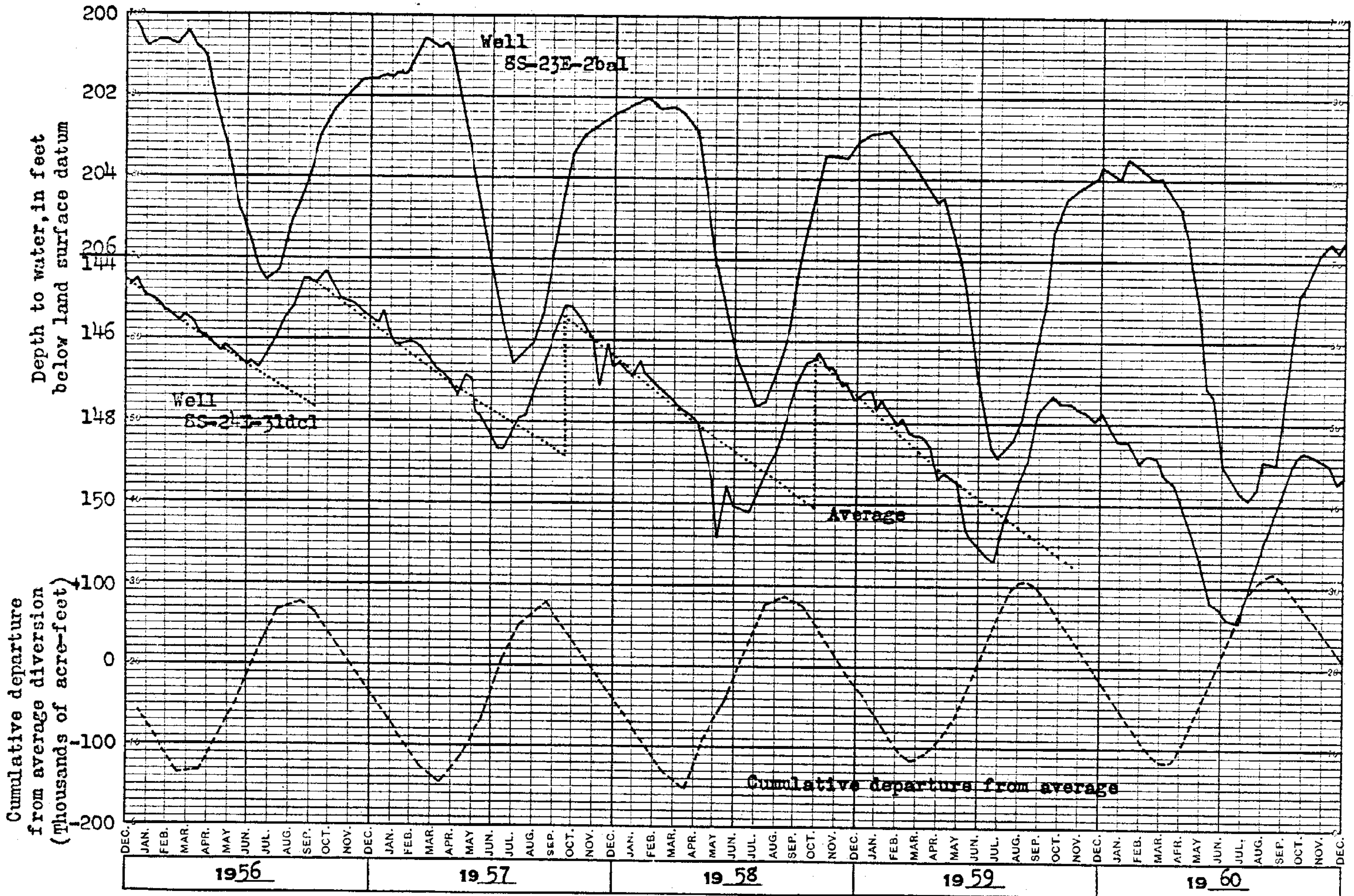


Figure 8.—Water level in two wells compared with cumulative departure from average diversion to Minidoka North Side canal.

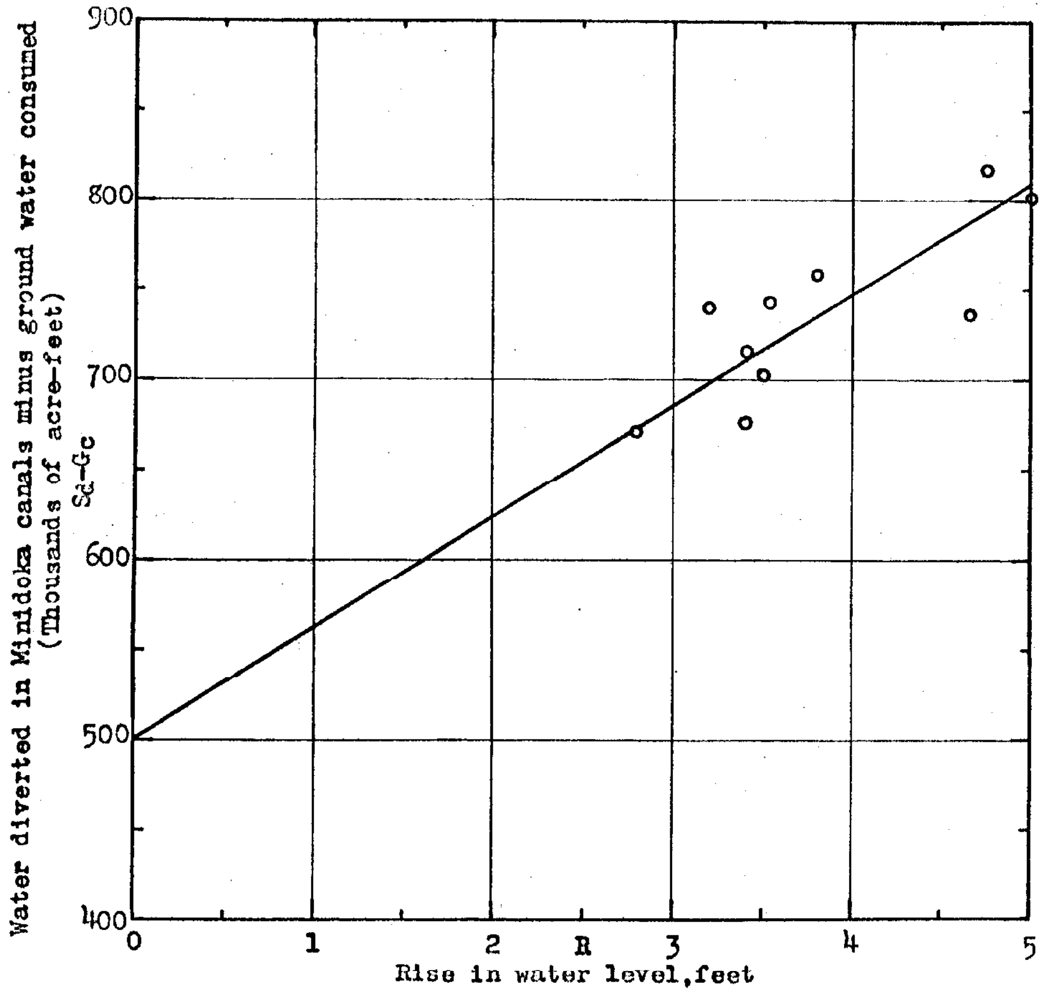


Figure 9.--Graph showing relation between surface-water diversion minus ground water consumed, and the rise in water level in well 8S-24E-31dc1.

water results in a rise in the water level of 4.5 to 5 feet in well 8S-24E-31dc1 (fig. 9) which is immediately adjacent to the irrigated area. Well 8S-23E-2ba1 is about 6 miles north of the project irrigated with surface water, and already in 1951, the water level in this well was being affected by local ground-water withdrawals. However, it appears that the rise in the water level in this well that can be attributed to the annual recharge from surface-water irrigation is roughly 2½ to 3 feet. The lag between diversion of surface water, and the first change in water-level trend in the well, caused by diversions, is about 3 to 3½ months.

More distant observation wells also show the effects of annual recharge from irrigation in the Minidoka Project area. All of these observation wells are farther north, so that they are nearer the area of ground-water pumping than they are to the surface-water area. Thus the rise caused by diversion of surface water is partially offset and obscured by the decline caused by ground-water withdrawals, especially since 1954. Hydrographs of 3 of these wells are shown in figure 10. Distances from the margin of tract irrigated with surface water and the time required for the effects of surface-water diversion to reach each well, for these three wells and the two shown in figure 8, are given in the following table:

| Well No. | Distance from margin of Minidoka Project area (miles) | Time required for effects of recharge from surface water (days) |
|---|---|---|
| 8S-24E-31dc1 | 0 | 0-10 |
| 8S-23E- 2ba1 | 6 | 90-100 |
| 7S-24E- 2ad1 | 10 | 100 |
| 5S-23E-17ca1 | 20 | 150 |
| 4S-24E- 6bb1 | 29 | 160-170 |

## Feasibility of recharge in selected areas

In a previous section of the report it was shown that large areas of the Snake River Plain were eliminated from consideration as potential recharge sites because of unfavorable topographic situation, excessive distance from a suitable water source, or nonavailability of a satisfactory surface site.

Several generally favorable areas remained and these are described in more detail in this section.

### Roberts-Plano area

The Roberts-Plano area extends westward from the Egin Bench in the vicinity of Plano to the vicinity of Roberts (fig. 11).

More than half the area included on the map is eliminated from consideration for recharge by water spreading because it is occupied by farms and other developments. Much of the rest of the area is public domain used only for cattle grazing.

#### Geologic features

Almost all the area is underlain by basaltic lava flows of the Snake River Group. The only exception is some small areas of silicic volcanic rocks north of Egin Lakes and southeast of Rexburg. Both of these are at too high an altitude to be considered for recharging.

In the southeastern part of the area the basalt is overlain by channel, flood plain, and alluvial fan deposits from Henrys Fork, and the Teton and Snake Rivers. The deposits are chiefly coarse sand and gravel, but include some fine sand and silt.

The thickness of these alluvial deposits varies greatly. A few buttes protrude through them, including Menan Buttes and Lewisville Knolls. Elsewhere the thickness ranges from a few to more than 260 feet, according to the few available well logs.

Basalt is at the surface or is mantled by thin windblown deposits in the northwestern three-fifths of the area shown on the map. Low domes mark several centers of extrusion. The most important of these are Little Grassy Butte, about 8 miles west of Plano, and Roberts Butte, about 10 miles northwest of Roberts. According to P. R. Stevens (personal communication) who mapped the 16 townships T. 5-8 N., R. 35-38 E. in connection with another project, the lava flows from Roberts Butte, and west of Roberts are the oldest exposed in the area. The lavas from Little Grassy Butte, those north of Mud Lake, and those north of Little Grassy Butte, are the youngest. All the surficial basalts in this area are believed to be of Pleistocene age. Some of the earlier flows, not exposed, but penetrated by wells, may possibly be as old as Pliocene age.

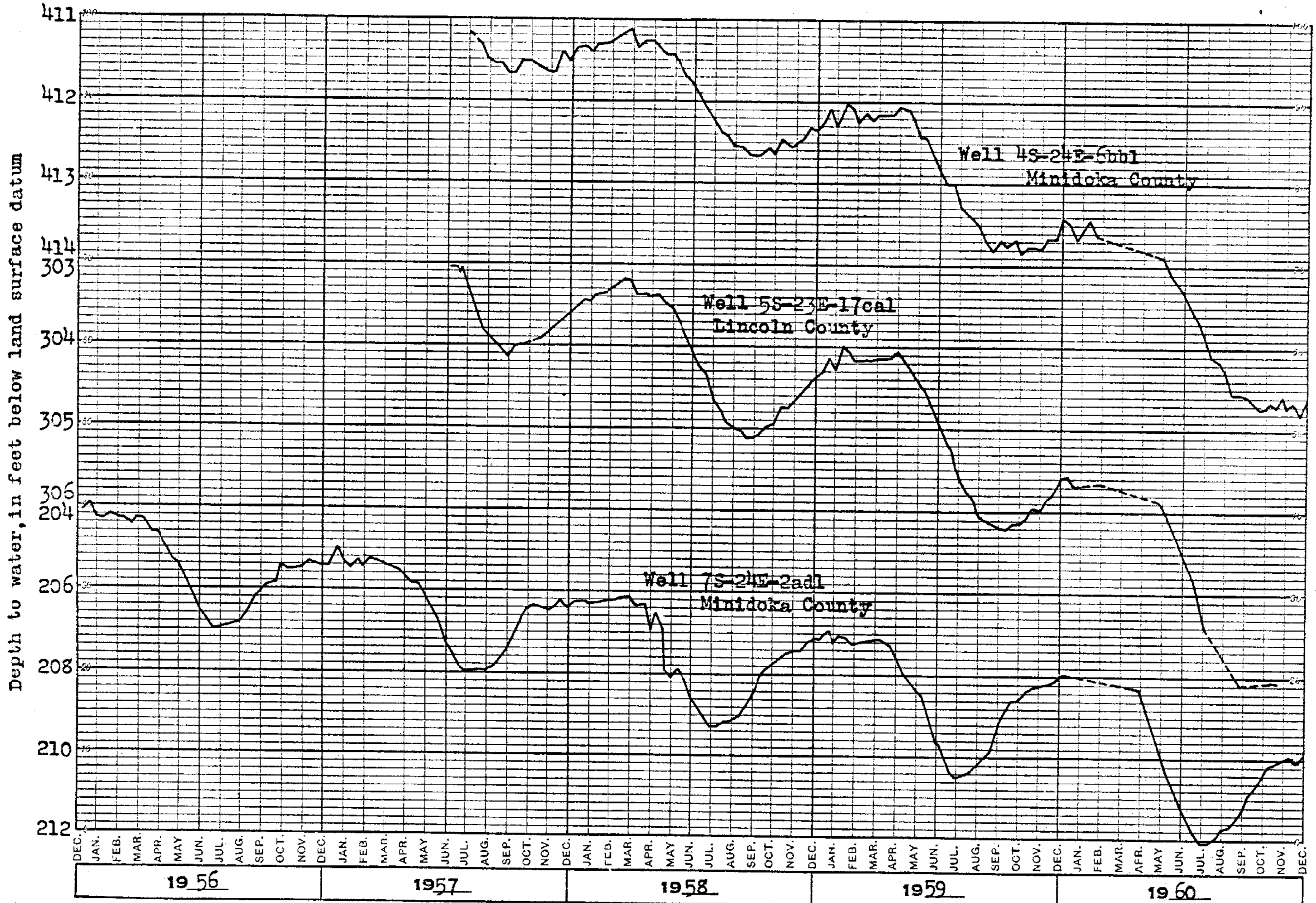


Figure 10.--Hydrographs of wells 7S-24E-2adl, 5S-23E-17cal, and 4S-24E-6bbl.

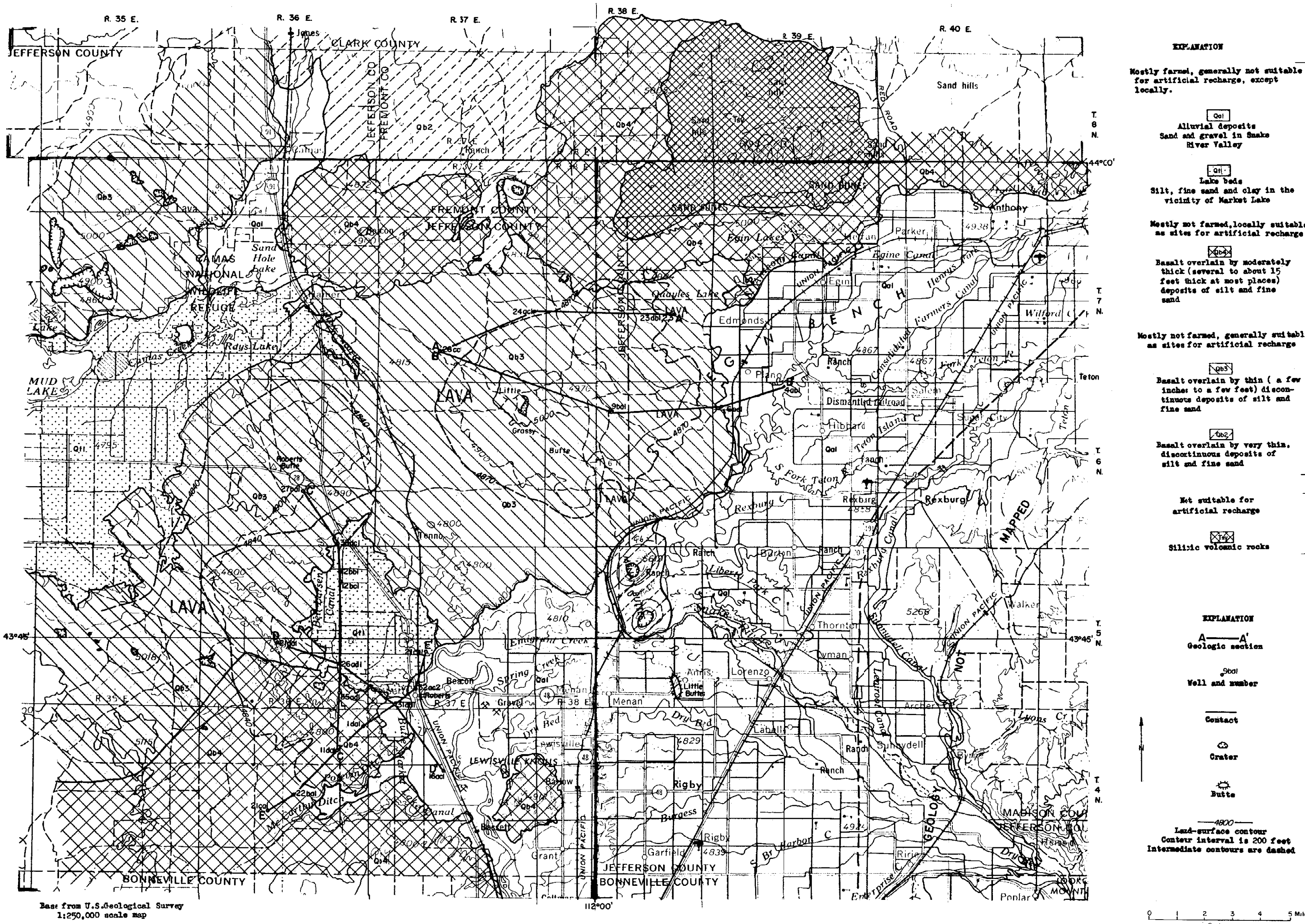


Figure 11.—Map of the Roberts-Plano area showing geologic features relating to recharge feasibility.

The lava flows are characteristically medium gray to black, olivine basalt, commonly open-textured or vesicular. The flow surfaces are very rough and irregular, with many collapse features and pressure ridges. Collapse features range from bowl-shaped depressions a few yards in diameter to very irregular interconnected depressions hundreds of yards across. The nature of the surface of the basalt is shown in the figures 12a and 12b. These photos show many but by no means all of different types of surficial features that are of significance in spreading of water for recharge.

Windblown sand and silt mantle the basalt throughout the area. A major source for these materials is to the west, in the Mud Lake area, and another source is to the southwest, in the vicinity of Roberts. Winds from the west-southwest have spread a blanket ranging in thickness from a few inches to perhaps 20 feet. The deposits are somewhat thicker on the north and northeast flanks of Little Grassy Butte than they are on the south and southwest flanks.

A stratum of sand and gravel is encountered beneath the basalt at an altitude of about 4,800 feet east of Grassy Butte. The few well logs available suggest that this stratum may continue through the area beneath Grassy Butte into the Market Lake area (fig. 13). In the vicinity of Market Lake the basalt is interbedded with lake and playa deposits (fig. 14).

## Ground-water features

The main aquifer is basalt and alluvium of the Snake Plain aquifer, generally at a depth of 50 to several hundred feet below land surface. The water table ranges from a few to about 120 feet below the land surface. Perched aquifers have developed in irrigated areas along the Henrys Fork downstream from St. Anthony and the Teton River downstream from Teton.

The perched aquifers are recharged by percolation from canals and irrigated tracts.

The perched aquifers discharge in part into Henrys Fork and the Teton River, but they also lose considerable water by percolation downward to the main water table.

Recharge to the main aquifer is in part from this downward percolation from perched aquifers, and also from percolation from Henrys Fork and the Teton River. The direction of ground-water movement in the aquifer is slightly south of west, (fig. 3).

The water table (fig. 3) is quite flat from the eastern margin of the area to approximately the railroad line between Roberts and Hamer. West of this line fine-grained materials underlie considerable areas in the vicinity of Roberts and Mud Lake and these deposits, apparently form a partial barrier to westward movement of ground water. East of the barrier the main water table is above an altitude of 4,750 feet; a few miles west of the barrier it drops to less than 4,600 feet. Through the barrier zone there are a number of different water tables in basalt flows from the west that interfinger with fine-grained lake deposits to the east.

The total underflow through the area is large. On the basis of data through the period 1920-28, Stearns and others (1938, p. 203) concluded that underflow away from the Egin Bench might be about 280,000 acre-feet a year. In a later study Mundorff and others (1960, p. 169) computed recharge to the aquifer upstream from Firth to be about 2,500,000 acre-feet per year. Their flow-net map (figure 3 of this report) shows an underflow of about 1,000 c.f.s., 725,000 acre-feet per year, through the aquifer between Hamer and Roberts, a distance of about 15 miles. That amount of underflow occurs under a hydraulic gradient of about 5 feet per mile between the Egin Bench and the barrier zone.

## Source of water and topographic factors

Surplus flood water from Henrys Fork could be diverted near St. Anthony at an altitude of about 5,000 feet. Although this is not the highest possible diversion point, diversions at higher altitudes would be somewhat less desirable because of less favorable topographic and other factors relating to diversion structures and canal alignment. Also, it appears that little advantage could be gained by diverting at higher points. Therefore, for this study, it is assumed that the maximum altitude which could be reached by recharge water is 5,000 feet. The area above 5,000 feet north of St. Anthony and Plano is shown on fig. 11. As can be seen from this map, a canal diverting at 5,000 feet near St. Anthony could convey water westward to an area west of Plano and Egin Lakes. Following approximately along the 5,000-foot contour, water theoretically could be conveyed westward and then northward to eventually reach an area west of Camas and north of Mud Lake. However, this would be a very lengthy route and ample recharge area apparently is available which is much nearer and which would be of equal benefit in recharge of the aquifer.

A few miles west of Plano an area occupied by a wide, low lava dome (Little Grassy Butte) could be used for recharge. However, this dome is entirely surrounded by a sag in the topography. Detailed topographic maps at a scale of 1:24,000 are available for the area east of longitude 112°00', but west of that longitude, and north of latitude 43°45' the only topographic map available is at a scale of 1:250,000 with a contour interval of 100 feet. Study of the available topographic map, air photos and field observation indicates that the maximum altitude by which a gravity canal could reach the lava dome is about 4,870 feet. Thus the part of the dome above that altitude is eliminated. The approximate location of the 4870-foot contour is shown on figure 11.

However, an area of roughly 100 square miles remains around the periphery of the dome to which water could be conveyed by gravity.

West of the railroad between Roberts and Hamer another large area of largely public domain appears suitable for recharge operations. However, a sag in the topography, followed by the railroad, separates this area

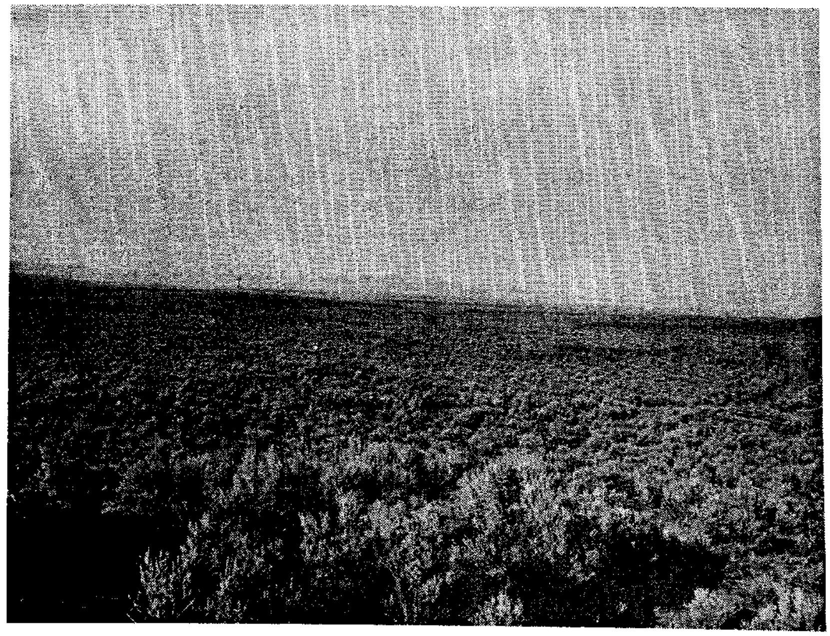

Figure 12a.--Basalt surface on north slope of Little Grassy Butte, T. 7 N., R. 38 E., section 31.

Figure 12b.--Close-up view of basalt in pressure ridge in same area as 12a. (Courtesy U. S. Bureau of Reclamation)

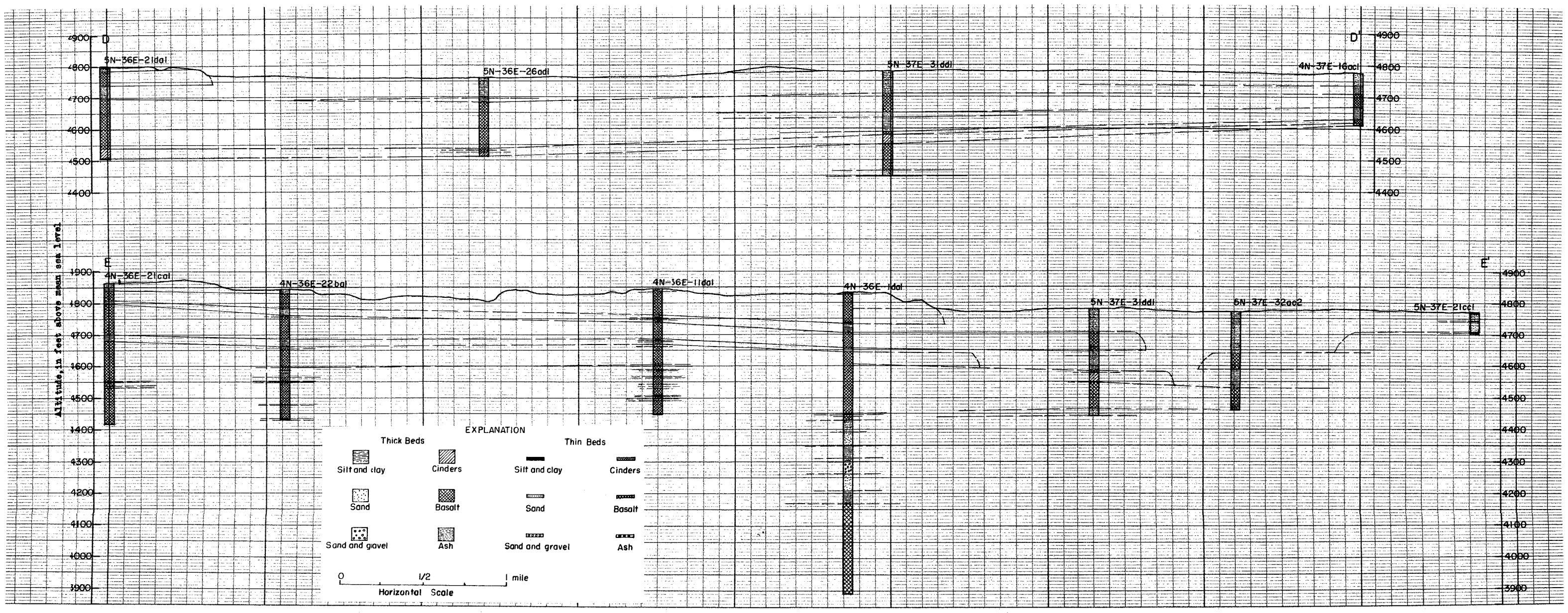


Figure 14.—Geologic sections D-D', and E-E', in the Roberts-Plano area.

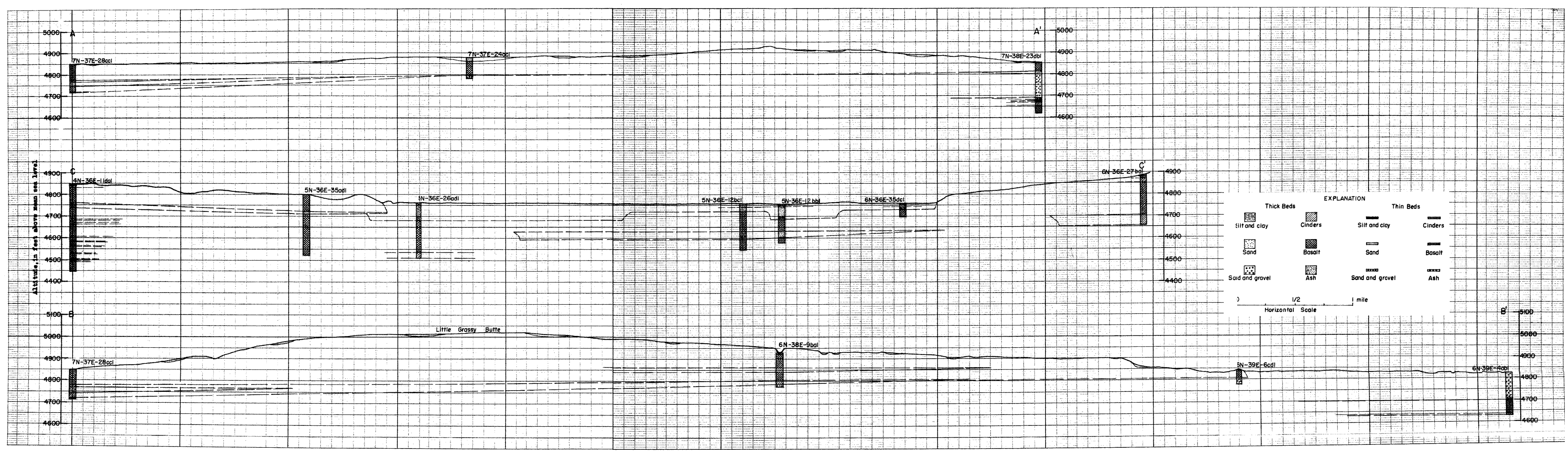


Figure 13.--Geologic sections A-A', B-B', and C-C', in the Roberts-Hamo area.

from the one to the east. Altitudes determined by the U. S. Coast and Geodetic Survey along the railroad indicate that a gravity canal probably could not cross this sag at an altitude above 4,830 or 4,840 feet. The approximate location of the 4,840 foot contour is shown on the map, figure 11.

## Recharge experiments

Two recharge experiments were conducted in the Roberts-Plano area in 1961 by the U. S. Bureau of Reclamation and the Geological Survey.

### Egin Lakes seepage study

Water is discharged into Egin Lakes from the Last Chance Canal by the Fremont-Madison Irrigation District to aid in subirrigation of the district. The lakes consist of a series of shallow ponds, in part separated by dikes and levees (fig. 15). U. S. Bureau of Reclamation personnel installed gages and other facilities for measuring pond elevations, inflow, outflow, and flow between ponds. They also bored 24 auger holes adjacent to the ponds. Surficial materials are light brown to gray, fine- to medium-grained sand; at a few places a little gravel was encountered just above the basalt. All holes except one bottomed on rock, presumed to be the surface of the uppermost basalt flow. Pertinent data on these auger holes are given in the table on the following page.

Most of the seepage loss was in the two largest ponds, labeled "A" and "B" on figure 15. The ponds are connected by a broad channel so that the water surface in both ponds is essentially the same. The area of these two ponds on April 20 and June 7 was determined with the aid of air photos. The ponded area for other times during the test was extrapolated or interpolated from those two measurements on the basis of pond elevation.

Inflow to the Egin Lakes area was measured at station M5 (fig. 15), and the discharge between small ponded areas and broadened segments of the channel was measured at stations M4 and M3. Inflow to ponds "A" and "B" was measured at M2 and outflow at M1. Seepage losses in the channel and small ponds between M5 and M2, and seepage losses from ponds "A" and "B" are summarized in table 4. Average daily seepage loss in the two larger ponds was slightly more than 0.25 acre-foot per acre.

In most auger holes the highest water levels measured were those made upon completion of the hole, or shortly thereafter. Hydrographs of some of the auger holes, and the pond level in ponds A and B are shown in figure 16. The relation of pond level and the perched water table is clearly shown. The slope of the perched water table away from the ponds is shown by the profiles in figures 17, 18 and 19.

The profiles suggest that there was some perching by silt in the pond bottom, and that below the pond a perched aquifer had developed, probably upon the basalt surface. The underlying basalt surface is irregular, and apparently channels the movement of water in preferred directions.

Table 3.--Auger holes in the Egin Lake recharge test area

| Auger hole no. | Altitude of Land surface | Altitude of Water level | Date of measurement 1961 | Depth of well (feet) | Reached basalt | Altitude of basalt surface | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | 4,883.21 | dry | - | 18.9 | Yes | 4,864.3 | |
| 2 | 4,881.77 | 4,871.17 | 4-4 | 16.9 | yes | 4,864.9 | |
| 3 | 4,881.11 | 4,875.41 | 4-4 | 14.0 | yes | 4,867.1 | |
| 4 | 4,881.30 | 4,879.90 | 4-4 | 6.4 | yes | 4,874.9 | |
| 5 | 4,881.87 | 4,879.37 | 4-4 | 5.6 | yes | 4,876.3 | |
| 6 | 4,883.48 | dry | - | 3.3 | yes | 4,880.2 | |
| 7 | 4,884.49 | 4,868.59 | 4-4 | 22.8 | yes | 4,861.7 | |
| 8 | 4,883.27 | 4,872.87 | 4-4 | 17.4 | yes | 4,865.9 | |
| 9 | 4,882.91 | 4,878.91 | 4-4 | 17.1 | yes | 4,865.8 | |
| 10 | 4,883.03 | 4,880.73 | 4-4 | 12.9 | yes | 4,867.8 | |
| 11 | 4,883.02 | 4,875.42 | 4-4 | 14.8 | yes | 4,868.2 | |
| 12 | 4,884.03 | dry | - | 11.8 | yes | 4,872.2 | |
| 13 | 4,881.50 | dry | - | 23.8 | yes | 4,857.7 | |
| 14 | 4,880.32 | 4,866.99 | 4-11 | 34.0 | yes | 4,846.3 | Cased to 16.8', caved below |
| 15 | 4,880.38 | 4,874.36 | 4-11 | 38.3 | yes | 4,842.1 | |
| 16 | 4,880.00 | 4,876.57 | 4-11 | 22.8 | yes | 4,857.2 | |
| 17 | 4,880.15 | 4,874.20 | 4-11 | 22.3 | yes | 4,857.9 | |
| 18 | 4,882.51 | 4,863.87 | 4-11 | 22.2 | yes | 4,860.3 | |
| 19 | 4,881.92 | 4,873.16 | 4-11 | 26.4 | yes | 4,855.5 | |
| 20 | 4,880.75 | 4,876.93 | 4-11 | 17.3 | no | 4,863.5 | |
| 21 | 4,880.01 | 4,876.57 | 4-11 | 49.9 | yes | 4,830.1 | |
| 22 | 4,880.35 | 4,874.37 | 4-11 | 31.5 | yes | 4,848.9 | |
| 23 | 4,880.35 | 4,874.38 | 4-11 | 30.3 | yes | 4,850.1 | |
| 24 | 4,882.47 | 4,872.53 | 3-11 | 23.5 | yes | 4,857.9 | |

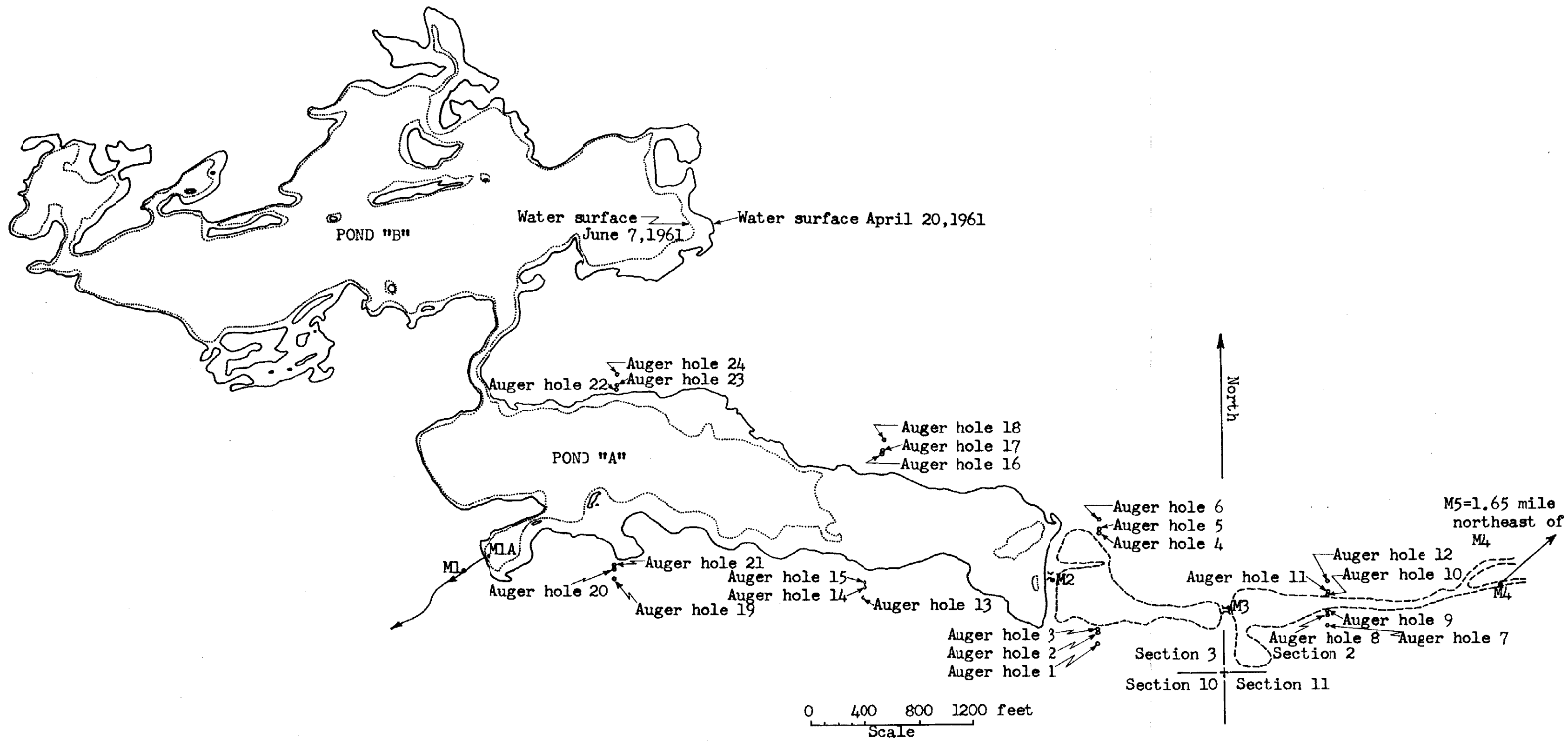


Figure 15.--Map showing Egin Lakes seepage-study area.

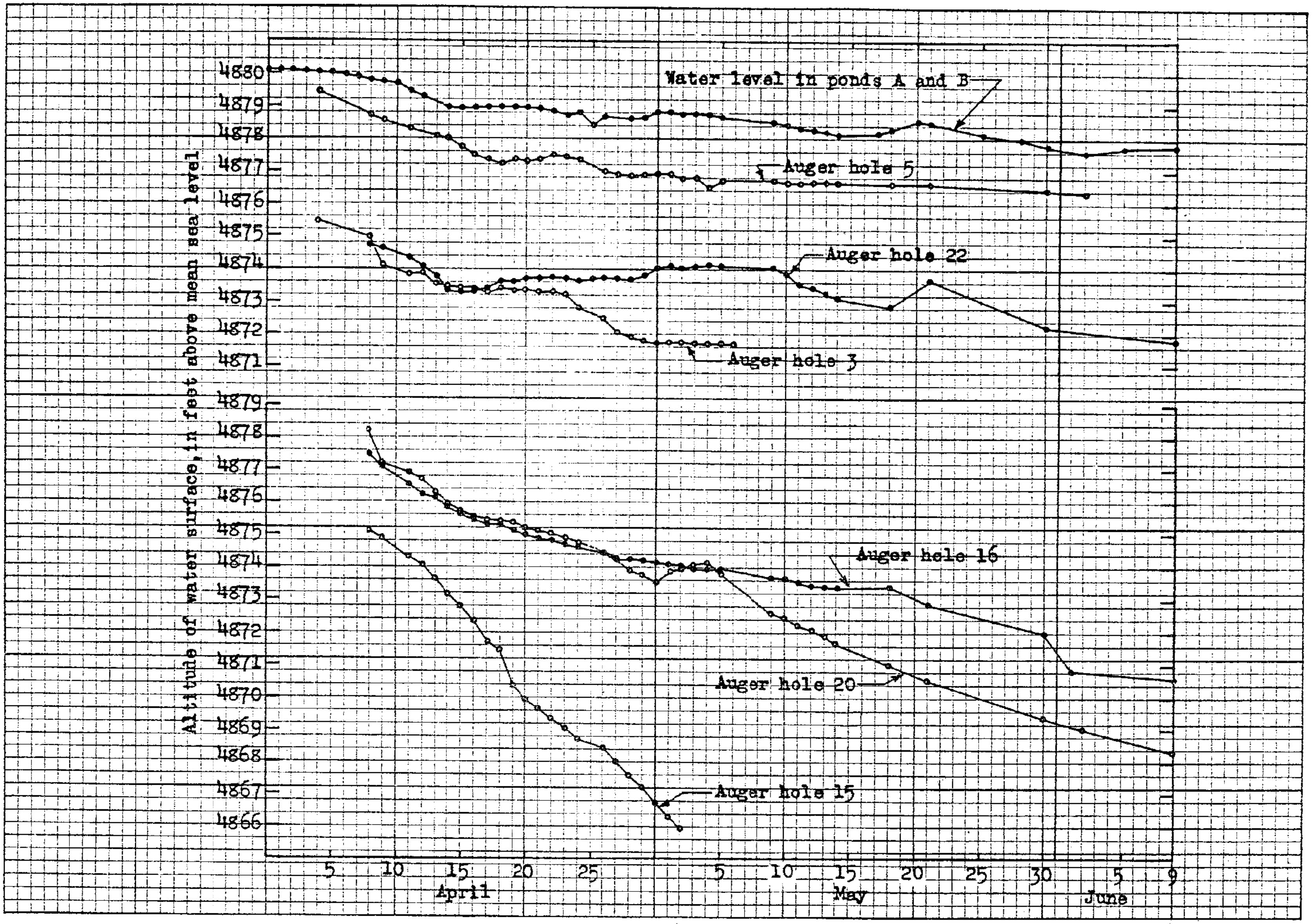


Figure 16.--Hydrographs of auger holes in the Egin Lakes area, and the water level in ponds A and B.

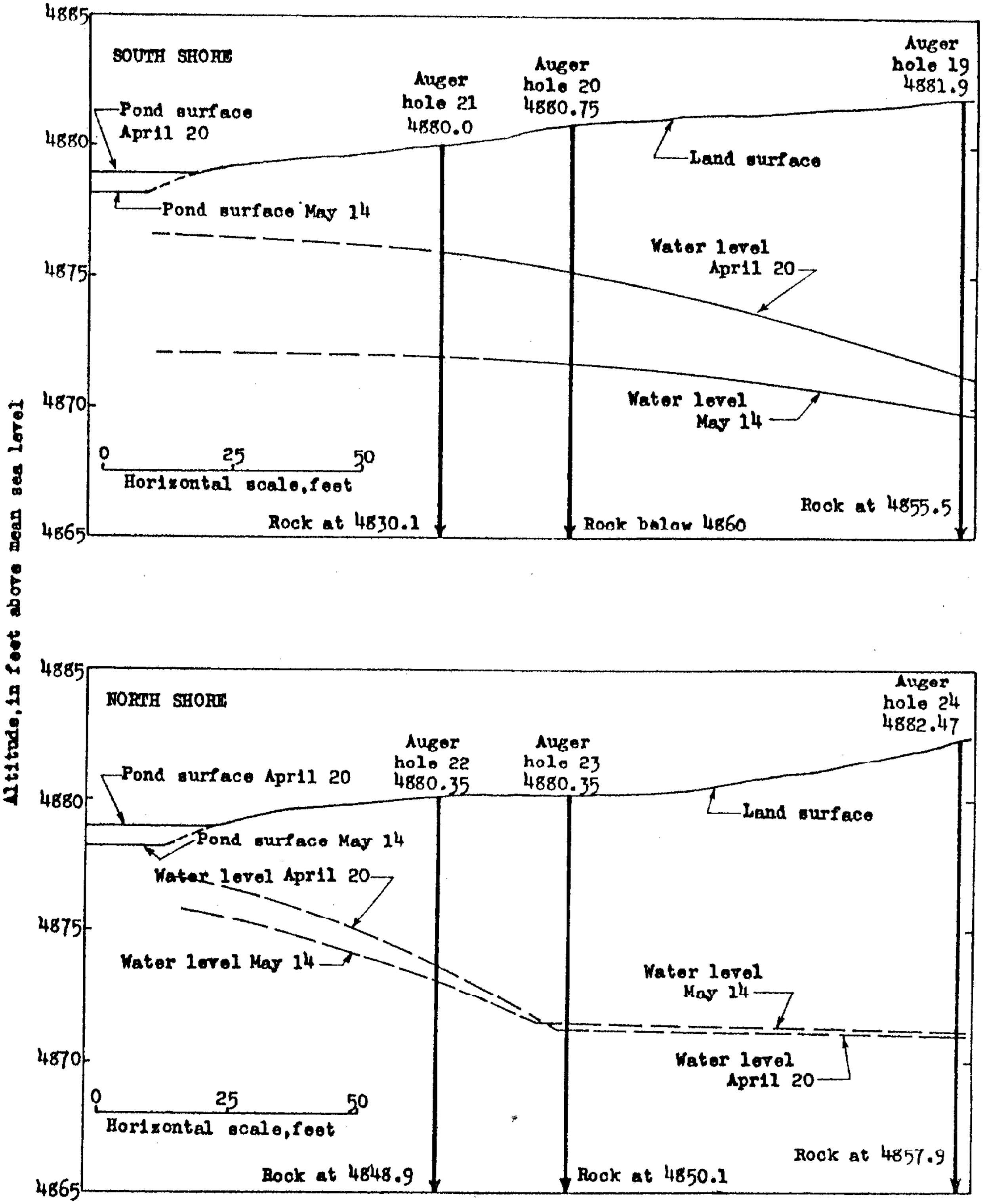


Figure 17.--Profiles from margin of Egin Lakes through auger holes 19, 20, and 21; and 22, 23, and 24.

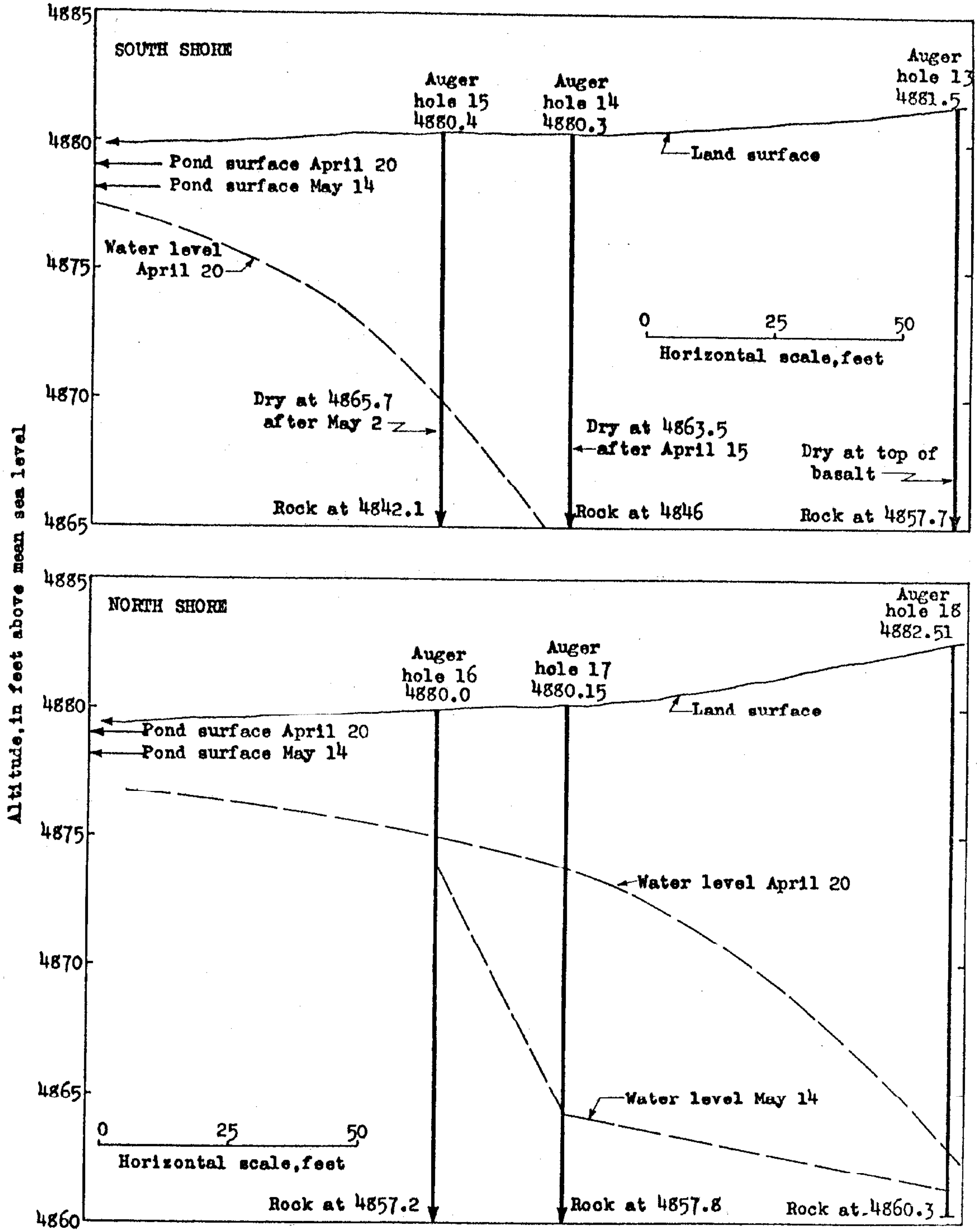


Figure 18.--Profiles from margin of Egin Lakes through auger holes 13, 14, and 15; and 16, 17, and 18.

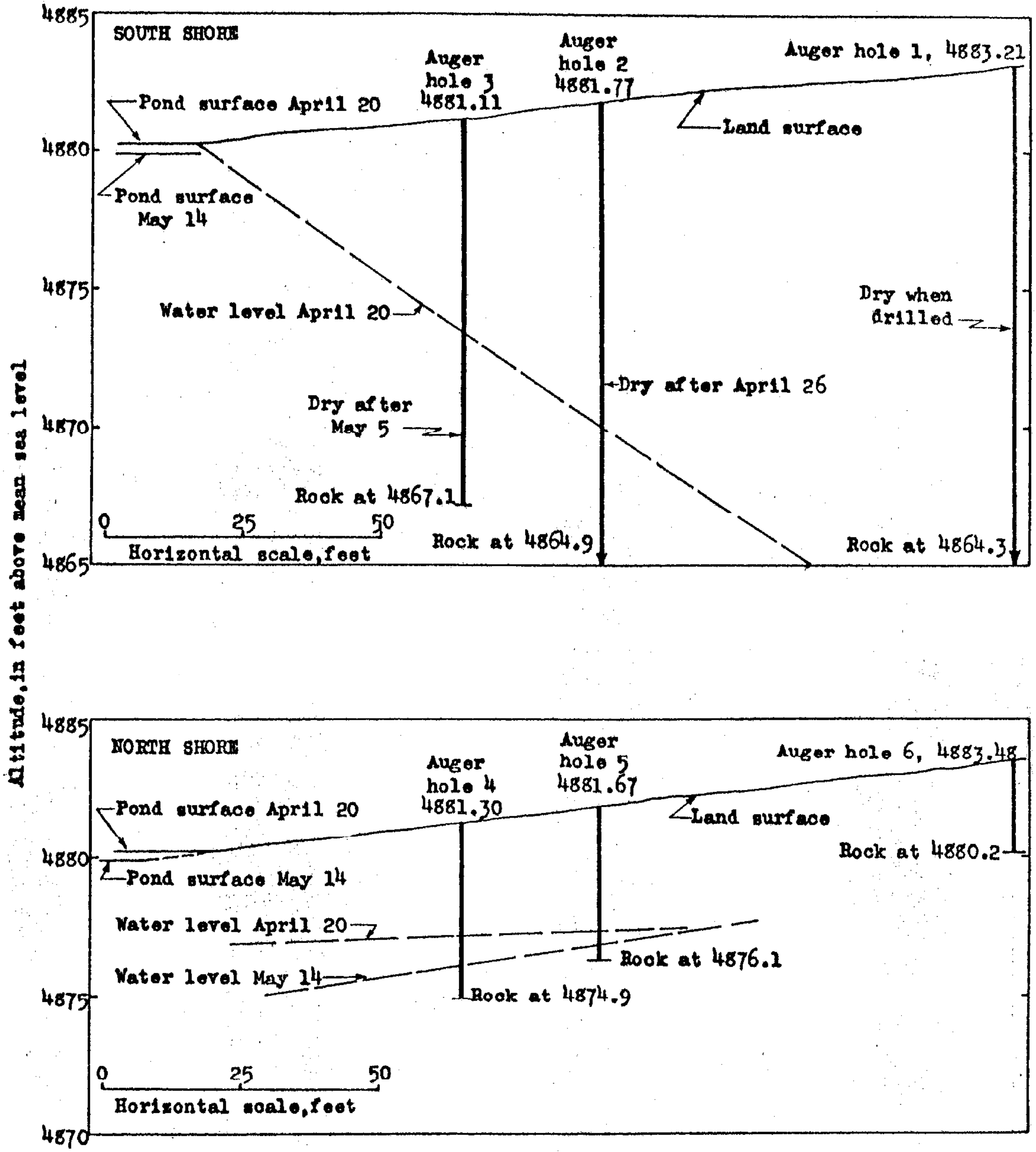


Figure 19.--Profiles from margin of Egin Lakes through auger holes 1, 2, and 3; and 4,5, and 6.

Table 4.--Summary of seepage losses, Egin Lakes seepage study

| Period (1961) | Average daily loss between M-5 & M-2 (acre-feet) | Average daily loss between M-2 & M-1 (acre-feet) | Average area of ponds A and B, (between M-2 & M-1) (acres) | Average daily change in volume of ponds A and B (acre-feet) | Average daily pond evaporation (acre-feet) | Average daily seepage loss from ponds A and B (acre-feet) | Average daily seepage loss (acre-feet per acre per day) |
|---|---|---|---|---|---|---|---|
| April 1- 5 | 9.6 | 62 | 270 | -1.1 | -2.6 | 58 | 0.224 |
| 6-10 | 6.8 | 38 | 256 | -19 | -2.0 | 55 | .198 |
| 11-15 | 17 | 28 | 223 | -38 | -2.1 | 44 | .160 |
| 16-20 | 16 | 35 | 211 | +.6 | -1.5 | 33 | .156 |
| 21-25 | 16 | 29 | 198 | -24 | -1.4 | 48 | .253 |
| 26-30 | 18 | 43 | 198 | -19 | -2.3 | 22 | .238 |
| May 1- 5 | 16 | 64 | 202 | -24 | -1.9 | 45 | .235 |
| 6-10 | 26 | 28 | 184 | -26 | -3.8 | 50 | .273 |
| 11-15 | 18 | 29 | 172 | -12 | -2.0 | 40 | .230 |
| 16-20 | 13 | 69 | 176 | +22 | -1.8 | 45 | .260 |
| 21-25 | 16 | 32 | 170 | -30 | -2.0 | 60 | .366 |
| 26-30 | 14 | 36 | 149 | -25 | -2.2 | 58 | .392 |
| May 31 - June 9 | 18 | 41 | 140 | -7 | -2.1 | 23 | .337 |
| Average | 15.7 | 41 | | | | 45 | .256 |

A composite sample was taken from each of the 24 auger holes for laboratory determination of permeability. The coefficients of permeability 1/ ranged from 2 to 240, and averaged 87. One-half the samples were between 40 and 160.

A uniform sand with a permeability of 87 would transmit about 10 acre-feet per acre per day by vertical percolation, from a ponding area if there were no perching layers below. The actual rate of seepage was only 2.5 percent of that rate, and the difference can be attributed to 3 different factors. (1) The temperature of the water was considerably below 60° F., probably about 40° to 45°, and the permeability to water of that temperature would be about 20 percent less than at 60° F. (2) Silt in the bottom of the pond apparently reduced the permeability of the top few inches of material. (3) The water was perched at the contact of the sand with the basalt. Cracks and crevices in the basalt are capable of taking large quantities of water, however, they comprise only a small percentage of the surface area of the basalt. Where sand has filled these crevices, the permeability is that of the sand filling. If, for example, the cracks and crevices comprise 5 percent of the area at the top of a flow overlain by sand, then obviously the permeability of the contact zone is only a small fraction of the permeability of either unit by itself.

## TW-12 pump-recharge test

A recharge test was made in an area west of the Egin Lakes in May and June, 1961. Water was pumped from well 7N-38E-23dbl (TW-12) into a group of shallow depressions north of the well (fig. 20). A low dike was built across a sag to prevent the water from spreading too far to the north, and to keep the pond to reasonable dimensions.

The basalt in this area is covered by several feet of fine-grained compact sand. A power auger was used to bore 15 test holes to obtain information on the thickness of overburden; and 12 additional holes were bored and cased with downspout for use as observation wells as the pond filled. After the test began it was found that additional auger holes were needed so auger holes 13-21 were bored by hand. Information on the test and auger holes is summarized in table 5. A composite sample was taken from each of auger holes 1-12 (except 10) and test holes 1-3, for laboratory determination of the coefficient of permeability. Permeabilities of the 14 samples ranged from 8 to 140 and averaged 87, the same as in the Egin Lakes area. Only 2 samples had permeabilities of less than 50.

Well 7N-38E-23dbl, which furnished the water for the test, is 236 feet deep and obtains water from basalt between 165 and 231 feet (see Section A-A', fig. 13). This aquifer is separated from the uppermost

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1/ The coefficient of permeability (Pm) is defined as the quantity of water, in gallons per day, that will flow through a section of aquifer 1 foot square under unit hydraulic gradient (1 foot per foot) at 60° F.

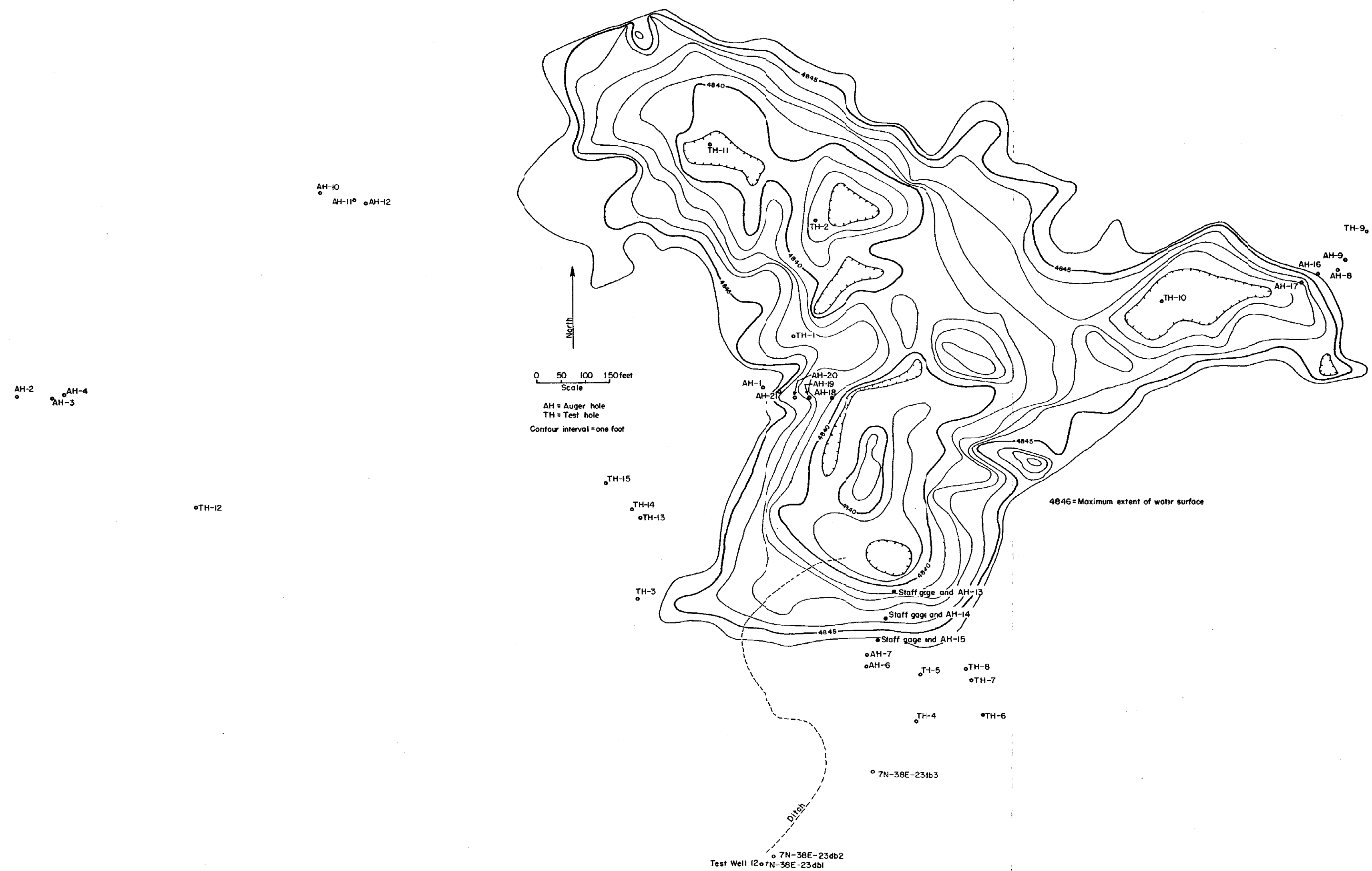



Figure 20.--Map of TW-12 pump-recharge test area.

basalt by 125 feet of silty sand and gravel. Well 7N-38E-23db2, 30 feet east, is 84 feet deep, and ends in the sand and gravel strata. Observations on the water levels in the two aquifers indicate that they are poorly interconnected, and that water in the sand and gravel is perched.

The production well, 23db1, was pumped at a rate of 2,400 to 2,600 g.p.m. Pumping began May 16, but because of engine trouble, pumping time totaled only 137 hours for the first 10 days of the test. Thereafter, pumping went somewhat better and total pumping time amounted to 673 hours between May 16 and June 21. During that period a total of 317 acre-feet of water was pumped. Data are summarized in table 6.

The average seepage loss from the pond during the test was 0.29 acre-foot per acre per day. However, the seepage rate decreased during the test, and after the test ended as the pond reduced in size.

The average thickness of sand overburden in the 27 test and auger holes which reached basalt was 6.5 feet. The average thickness of overburden in the 4 holes reaching basalt within the area actually ponded was 7.5 feet. Generally, the greatest thickness of overburden is found in the bottoms of the depressions, basalt is exposed at many places at higher points, at places with gaping cracks. It is probable that as the pond filled, the seepage rate should increase, and if the water reached open cracks and crevices in the basalt, seepage losses into these might be many times greater than through sandy and silty overburden.

Water-level measurements in the auger holes, illustrated in part by the profiles in figure 21, indicate that a perched water table developed on top of the basalt. However, the perched aquifer was never very much larger than the pond, and the margins of the perched aquifer were steep.

During the recharge test, a water-level recorder was in operation on well 7N-38E-23db2, which ends in the perched aquifer in sand and gravel between the two basalt flows. The water level in this well rose (fig. 22), beginning the day that the test began, and virtually ceased to rise the day pumping ended (fig. 22). This water table was about 30 feet below the shallow perched water table that developed beneath the pond. The rise in the lower perched water table is believed not to be related to seepage from the pond, but to some other cause, perhaps loading of the pond, or to a general water-table rise caused by some other factor. There are two reasons for this belief. First, the rise ended the day pumping ceased, yet seepage from the pond continued at nearly the same rate for a week longer. Second, the aquifer supplying the water for the recharge experiment also rose during the pumping period, and by an approximately similar amount (see fig. 23). Several measurements of the static level were made in the pumped well, 7N-38E-23db1 at times when the pump was off during the test period; also, a water-level recorder was operated on well 7N-38E-23db3, which is in the same aquifer, 300 feet from the pumped well.

## Summary

The seepage rates from the recharge experiments indicate that large areas would be required for recharging if only the bottoms of the depressions are utilized. For example, with a seepage rate of 0.25 acre-foot per acre per day, 4,000 acres would be required for recharging 1,000 acre-feet per day. However, as the water fills and overtops these depressions to spill from one to the other, open cracks and crevices in the basalt will furnish avenues for recharge at rates manyfold greater. Several methods of improving the intake are described in a later section of the report.

Considering the size of the area available for recharge, and the large quantities of water recharged from irrigation in nearby areas much less favorable for recharge, it is a reasonable conclusion that artificial recharge in this area would be successful.

## Probable effects of large-scale artificial recharge in the area

Specifically, the question is: What will be the changes in the hydrologic regimen if a certain quantity of water is added to the aquifer in this area? The effects of recharge can be evaluated by two basically different methods. These are: (1) analysis of the effects of presently occurring recharge, from streams and irrigation; and (2) theoretical analysis based on assumed coefficients of transmissibility and storage, and boundary conditions.

In a previous section of the report it was estimated that about 725,000 acre-feet of water was recharged to the aquifer each year by percolation loss from the streams and from irrigation. Recharge from the streams is a continuous process, but recharge from irrigation is a cyclic process that accounts for perhaps 300,000 to 400,000 acre-feet of the total annual recharge in the area. The effect of this cyclic recharge is shown by the hydrograph of well 7N-38E-23dbl (TW-12) (fig. 23) which is a few miles west of the irrigated area. Annual cyclic fluctuation in this well is about 4 feet. However, if recharge had not occurred, the water table would have continued to decline, as shown by the dashed line in figure 23. That is, recharge of 300,000 to 400,000 acre-feet over an area of 3 or 4 townships (120-150 square miles) during the irrigation season results in a rise in the main water table of about 6 feet in a well a few miles from the edge of the irrigated area.

Periodic measurements made on observation wells farther to the west are insufficient to adequately define the spread of the recharge mound.

In their report on ground water for irrigation in the Snake River basin, Mundorff and others (1960, p. 189) estimated that pumping 112,500 g.p.m. from 50 wells (about 250 c.f.s.) in the Roberts-Plano area would lower the water table about 3.5 to 4.5 in individual wells at the end of one season's pumping (122 days). Drawdown at a point 2 or 3 miles from the line of wells would be on the order of 3 feet. Buildup of the water table by recharge of 250 c.f.s. for 122 days would be the same amount, about

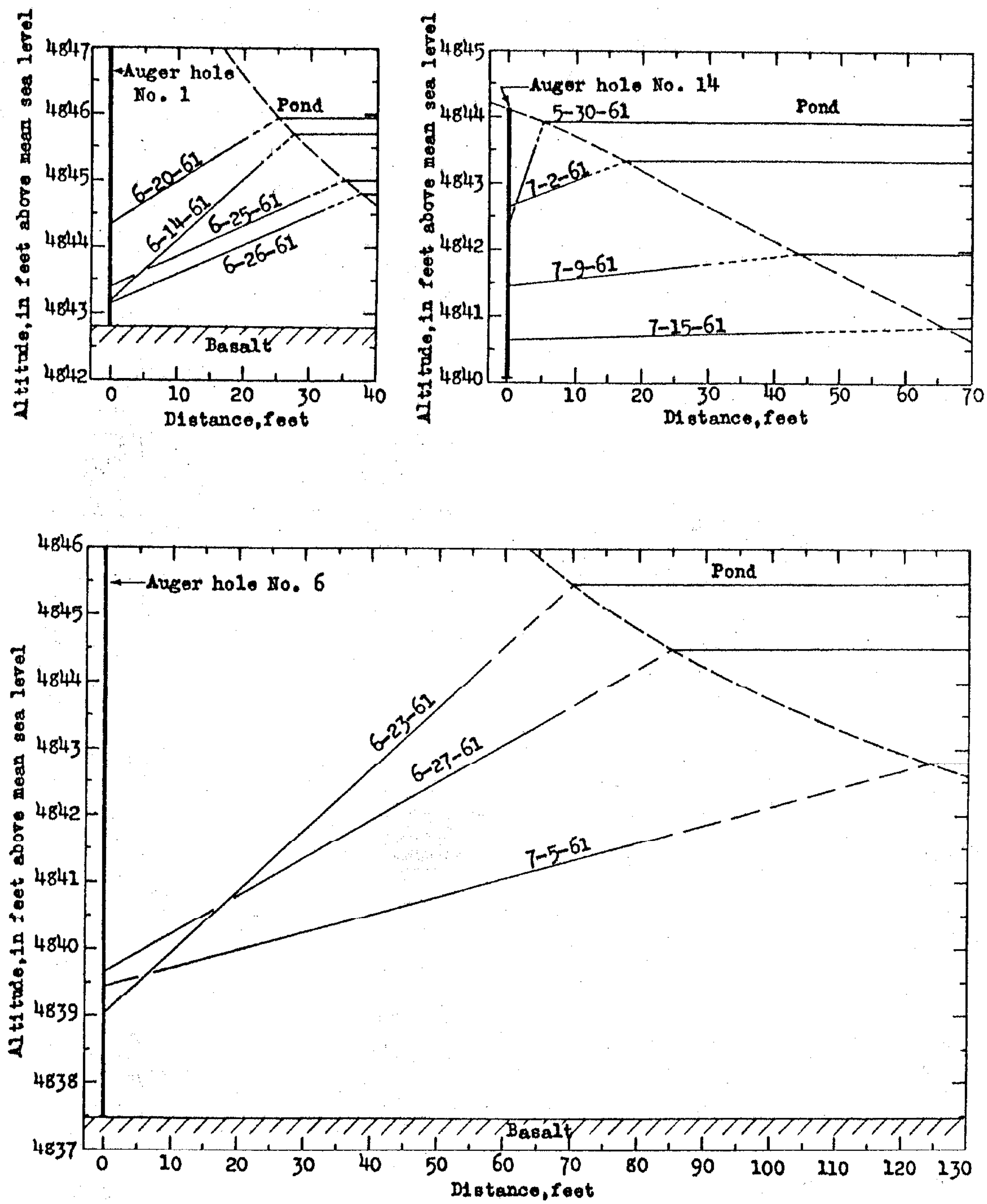



Figure 21.--Profiles of water surface between the pond and selected auger holes.

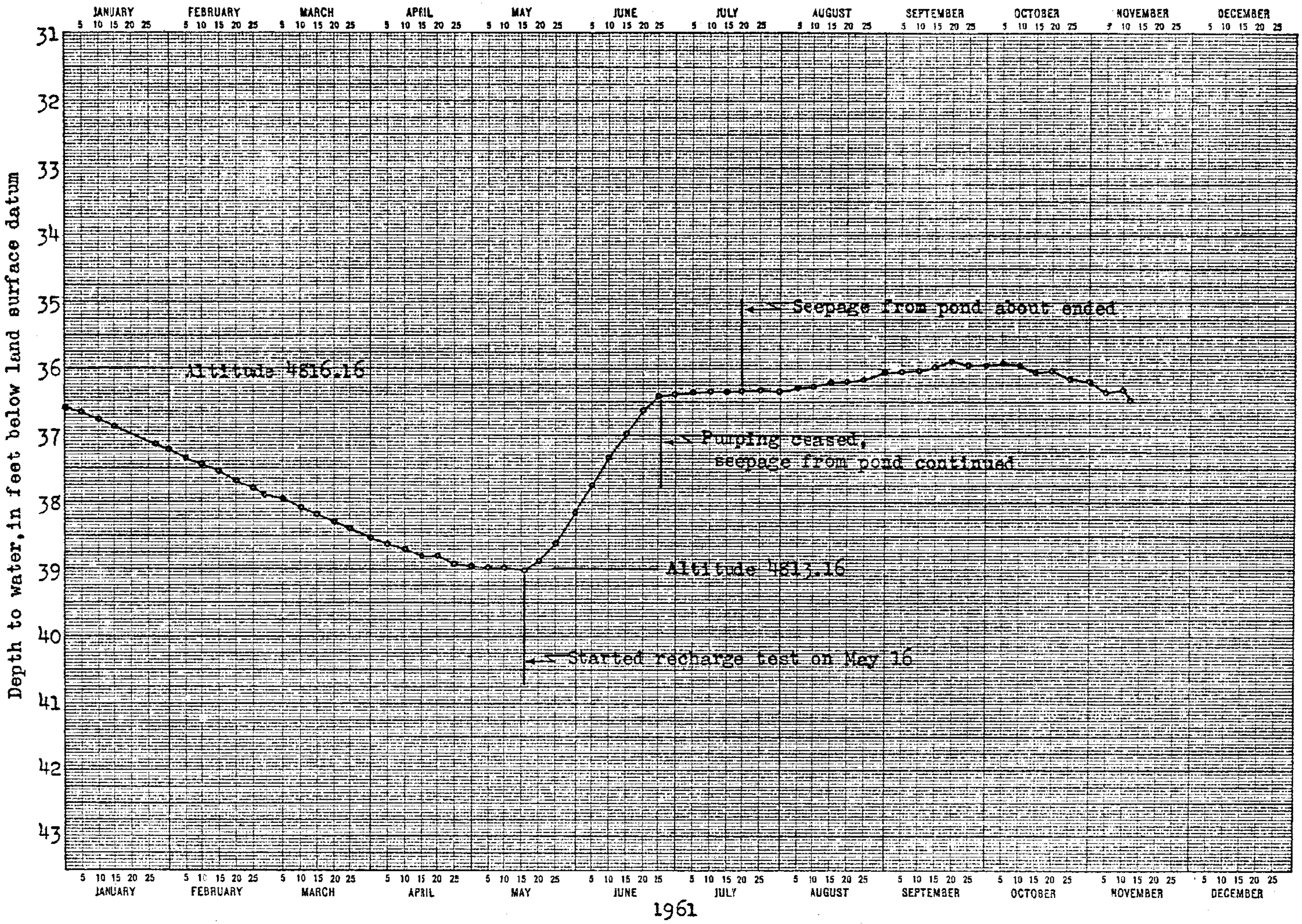



Figure 22.--Hydrograph of well 7N-38E-23db2, preceeding, during, and following TW-12 punp-recharge test.

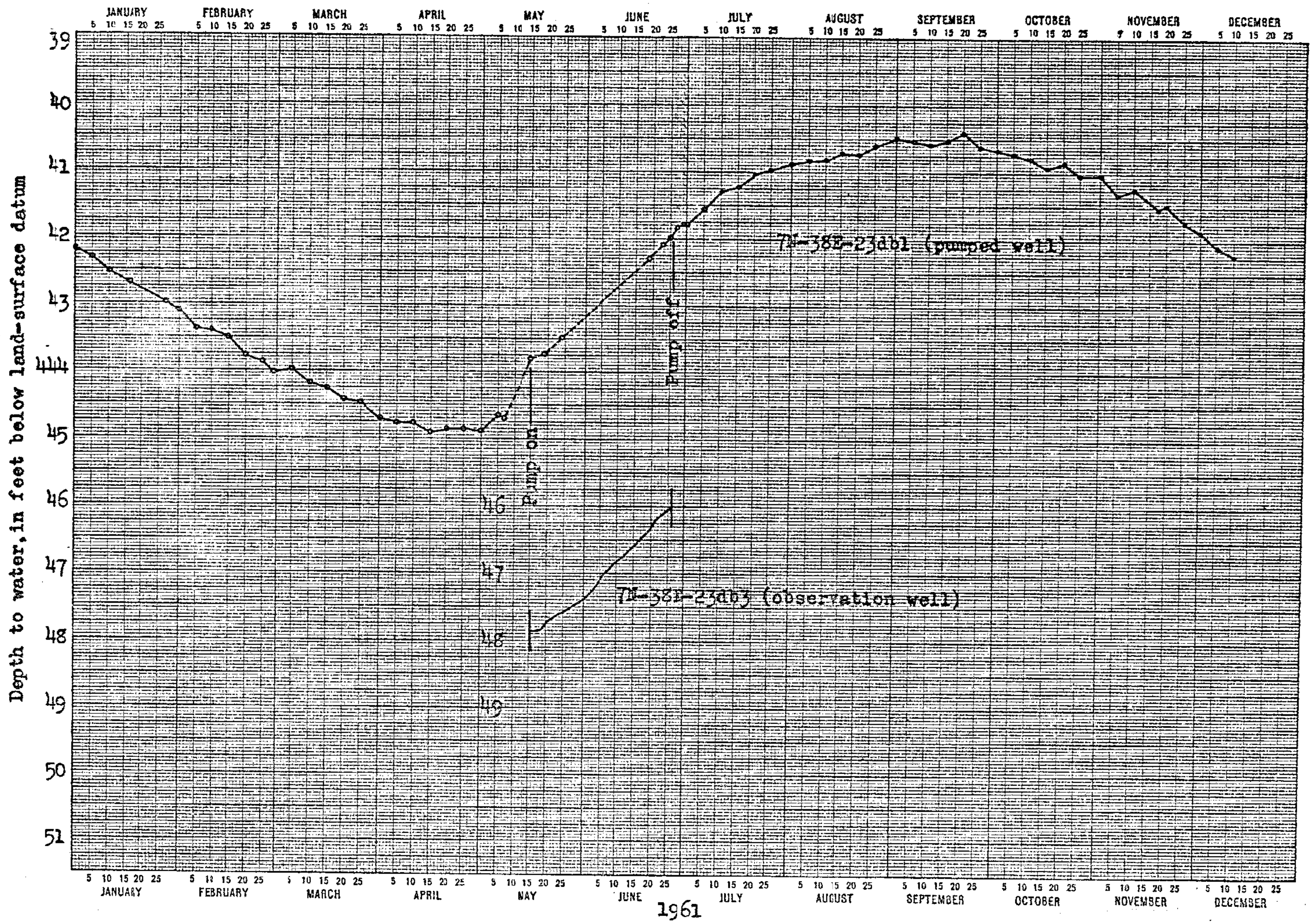



Figure 23.--Hydrographs of well 7N-38E-23db1 and 23db3.

Table 5.--Test and auger holes in the TW-12 recharge test area

| Test hole no. | Depth to rock 1/ | Test hole no. | Depth to rock 1/ | Test hole no. | Depth to rock 1/ |
|---|---|---|---|---|---|
| 1 | 14.1 | 6 | 4.0 | 11 | 2.3 |
| 2 | 7.6 | 7 | 3.3 | 12 | 3.6 |
| 3 | 2.3 | 8 | 8.6 | 13 | 3.0 |
| 4 | 6.3 | 9 | 7.3 | 14 | 2.6 |
| 5 | 7.0 | 10 | 6.2 | 15 | 4.0 |

| Auger hole No. | Depth to rock 1/ | Altitude of Land Surface | Altitude of Basalt | Auger hole no. | Depth of Hole | Altitude of land surface |
|---|---|---|---|---|---|---|
| 1 | 6.4 | 4,849.23 | | 13 | 3.0 | 4,842.64 |
| 2 | 9.6 | 4,852.20 | | 14 | 4.0 | 4,844.08 |
| 3 | 7.6 | 4,849.64 | | 15 | 5.4+ | 4,846.62 |
| 4 | 5.6 | 4,848.44 | | 16 | 4.1+ | 4,845.20 |
| 5 | 9.6 | 4,852.51 | | 17 | 2.8 | 4,842.19 |
| 6 | 12.7 | 4,850.19 | | 18 | 4.3+ | 4,840.91 |
| 7 | 9.5 | 4,849.11 | | 19 | 6.5+ | 4,842.36 |
| 8 | 5.6 | 4,848.50 | | 20 | 5.0 | 4,845.18 |
| 9 | 5.3 | 4,849.75 | | 21 | 6.5 | 4,846.83 |
| 10 | 7.3 | 4,848.51 | | | | |
| 11 | 7.2 | 4,849.37 | | | | |
| 12 | 5.6 | 4,848.62 | | | | |

1/ All test holes, and auger holes 1-12 bottomed on basalt.

Table 6.--Data from TW-12 Pump Recharge Test

| Period | Number of days | Water pumped (acre-feet) | Pond elevation 1/ (feet above sea level) | Change in elevation | Volume 1/ of pond (acre-feet) | Change in storage (acre-feet) | Pond evaporation (acre-feet) | Seepage (acre-feet) | Average ponded area (acres) | Seepage (acre-feet acre day) |
|---|---|---|---|---|---|---|---|---|---|---|
| May 16-18 | 3 | 18.6 | 4,841.53 | | 16.2 | +16.2 | 0.10 | 2.2 | - | - |
| 19-20 | 2 | 11.7 | 4,841.49 | -0.4 | 16 | - .2 | .20 | 11.7 | 8.9 | 0.66 |
| 21-25 | 5 | 35.6 | 4,842.99 | +1.50 | 32.5 | +16.5 | .71 | 18.4 | 11.5 | .32 |
| 26-30 | 5 | 52.6 | 4,843.99 | +1.00 | 51.0 | +18.5 | 1.38 | 32.7 | 17.3 | .38 |
| May 31-June 4 | 5 | 50.0 | 4,844.82 | + .83 | 67.5 | +16.5 | 1.27 | 32.2 | 19.5 | .33 |
| June 5-9 | 5 | 47.0 | 4,845.51 | + .69 | 82.5 | +15.0 | 1.60 | 30.4 | 22.0 | .26 |
| 10-14 | 5 | 44.5 | 4,845.75 | + .24 | 88.3 | + 5.8 | 1.92 | 36.8 | 23.9 | .31 |
| 15-19 | 5 | 43.1 | 4,845.91 | + .16 | 92.2 | + 3.9 | 2.44 | 36.8 | 24.9 | .30 |
| 20-21 | 2 | 13.8 | 4,845.89 | - .02 | 92.1 | - .1 | 1.38 | 12.5 | 24.7 | .25 |
| 22-25 | 4 | 0 | 4,844.85 | - .96 | 68.0 | -24.1 | 2.0 | 22.1 | 23.0 | .24 |
| 26-July 1 | 7 | 0 | 4,843.45 | -1.40 | 41.1 | -26.9 | 2.9 | 24.0 | 18.0 | .19 |
| July 2-7 | 6 | 0 | 4,842.25 | -1.20 | 23.3 | -17.8 | 1.8 | 16.0 | 13.5 | .20 |
| 8-13 | 6 | 0 | 4,841.11 | -1.14 | 9.4 | -13.9 | 1.3 | 12.6 | 9.5 | .22 |
| 14-19 | 6 | 0 | 4,839.70 | -1.41 | 1.9 | 7.5 | .5 | 7.0 | 5.0 | .23 |
| Total - - - - | | 316.9 | | | | | | | | |
| Average - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - | | | | | | | | | | 0.29 |

1/ At end of period listed.

3 feet, assuming the same hydraulic factors. Buildup for a recharge rate of 500 c.f.s. would be double the amount for 250 c.f.s.

The Snake Plain aquifer discharges into the American Falls Reservoir reach and the Hagerman Valley reach, as described earlier in the report. Flowlines on figure 3 indicate that, of the total underflow in the section at right angles to the flowlines between Blackfoot and Arco, about 40 percent discharges into the American Falls Reservoir reach and 60 percent into the Hagerman Valley reach. Therefore, about 40 percent of the water recharged in the Roberts-Plano area probably would be tributary to the American Falls Reservoir reach and 60 percent would be tributary to the Hagerman Valley reach.

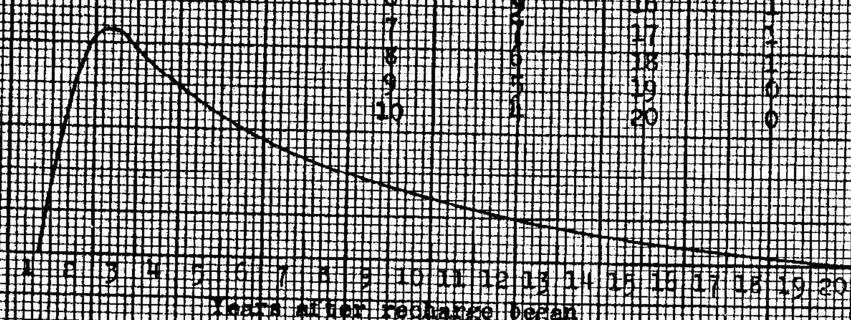
The rate at which the recharge mound spreads, and the time-distribution of the increased discharge into the American Falls Reservoir reach is of considerable importance. A mathematical analysis can be made, by assigning average values for the coefficients of transmissibility and storage, and making some simplifying assumptions regarding boundaries. The boundaries shown on figure 3 are too complex for solution. They can be approximated by disregarding the boundary between Hamer and Idaho Falls, and shifting the remaining boundaries to form a rectangle with straight-line negative boundaries on the northwest, southeast, and northeast, and one positive boundary, representing the American Falls discharge area, to the southwest. Solution with even this simplified set of boundaries is very tedious and requires a great amount of time. Theoretically, an infinite series of image wells are required; actually with the configuration assumed, 19 image wells suffice within the time limits used. However, with the simplified boundaries, and 19 image wells, the time required for a solution was still too great, so the problem was further simplified. The negative boundaries were disregarded, and only one image well was used, reflected across an assumed straight-line positive boundary crossing the flowlines at about the upper end of American Falls Reservoir. With this assumption a graph, figure 24, was constructed showing the time-distribution in head changes in the aquifer at a point 5 miles upgradient from the positive boundary. Assuming that the changes in head are in direct ratio to changes in underflow, the area under the curve represents the total gain in underflow, at the point, caused by addition of a specific quantity of water in the Roberts-Plano area and the percentage of gain in underflow can be determined for each year. The curve was constructed by assuming continuous addition of 100,000 g.p.m. for a period of six months; however, the rate of discharge does not affect the percentage distribution of the gain in discharge.

Use of only the positive boundary, and disregarding the 3 negative boundaries, may be justified by the following line of reasoning. The magnitude of the "wave" of recharge is greatly affected by the negative boundaries, but the rate of spread of the recharge mound toward the positive boundary would not be. As a check, several points were computed using the 19-image well array. These points plotted above, but generally parallel to the curve in figure 24. The curve was used in constructing the table on the following page which can be used to determine the gain in discharge in any year, caused by recharge of a specific quantity of water.

Table 7.--Increased inflow to American Falls Reservoir reach caused by recharge in the Roberts-Plano area 1/

| Years since recharging began | Years of consecutive recharging | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | Cumulative | 3 | Cumulative | 4 | Cumulative | 5 | Cumulative |
| 1 | 0 | | 0 | | 0 | | 0 | | 0 |
| 2 | 12 | 0 | 12 | | 12 | | 12 | | 12 |
| 3 | 15 | 12 | 27 | 0 | 27 | | 27 | | 27 |
| 4 | 13 | 15 | 28 | 12 | 40 | 0 | 40 | | 40 |
| 5 | 11 | 13 | 24 | 15 | 39 | 12 | 51 | 0 | 51 |
| 6 | 9 | 11 | 20 | 13 | 33 | 15 | 48 | 12 | 60 |
| 7 | 7 | 9 | 16 | 11 | 27 | 13 | 40 | 15 | 55 |
| 8 | 6 | 7 | 13 | 9 | 21 | 11 | 32 | 13 | 45 |
| 9 | 5 | 6 | 11 | 7 | 18 | 9 | 27 | 11 | 38 |
| 10 | 4 | 5 | 9 | 6 | 15 | 7 | 22 | 9 | 31 |
| 11 | 4 | 4 | 8 | 5 | 13 | 6 | 19 | 7 | 26 |
| 12 | 3 | 4 | 7 | 4 | 11 | 5 | 16 | 6 | 22 |
| 13 | 3 | 3 | 6 | 4 | 10 | 4 | 14 | 5 | 19 |
| 14 | 2 | 3 | 5 | 3 | 8 | 4 | 12 | 4 | 16 |
| 15 | 2 | 2 | 4 | 3 | 7 | 3 | 10 | 4 | 14 |
| 16 | 1 | 2 | 3 | 2 | 5 | 3 | 8 | 3 | 11 |
| 17 | 1 | 1 | 2 | 2 | 4 | 2 | 6 | 3 | 9 |
| 18 | 1 | 1 | 2 | 1 | 3 | 2 | 5 | 2 | 7 |
| 19 | 0 | 1 | 1 | 1 | 2 | 1 | 3 | 2 | 5 |
| 20 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 3 |

1/ In percent of quantity of water recharged annually.




Percent of area under the curve

| Year | Percent (rounded) | Year | Percent (rounded) |
|---|---|---|---|
| 1 | 0 | 11 | 4 |
| 2 | 11 | 12 | 3 |
| 3 | 15 | 13 | 3 |
| 4 | 13 | 14 | 2 |
| 5 | 11 | 15 | 2 |
| 6 | 9 | 16 | 1 |
| 7 | 7 | 17 | 1 |
| 8 | 6 | 18 | 1 |
| 9 | 5 | 19 | 0 |
| 10 | 4 | 20 | 0 |

Figure 24.--Time-distribution of head changes in Snake plain aquifer.

The table shows that, if a certain amount of water were recharged to the aquifer west of Plano during a single season, the entire effects would be dissipated in about 20 years, with the rate of dissipation, in the American Falls area being 0% in the first year, 12% in the second, 15% in the third, and so on. With five successive seasons of recharge, the amount of recharge being the same each year, the rate of dissipation of the annual addition of this recharge would be 0 percent in the first year, 12 in the second, 27 in the third, 40 in the fourth, and so on.

Although, because of the simplifying assumptions made, the curve and tabular data may be in considerable error, they do give a general indication of the time-distribution of return to American Falls Reservoir.

The above discussion should not be taken to mean that the only benefit would be increase in discharge into the American Falls Reservoir and Hagerman Valley reaches of Snake River. In the process, the water table would be maintained at higher levels. For example, recharge of 1,000,000 acre-feet of water would maintain the water table at an altitude which would have resulted if pumping had been 2,000,000 acre-feet less (assuming 1,000,000 consumptive use). Or, recharge of 1,000,000 acre-feet would permit pumping of 2,000,000 acre-feet more water, without any additional drawdown. Thus, the benefits would be partly in the increased discharge into American Falls Reservoir, and partly in the maintenance of higher water levels.

## Idaho Falls area

The Idaho Falls basalt recharge area extends west and southwest from Idaho Falls (fig. 25). The area which might be suitable for recharge by spreading forms an irregular, discontinuous strip a few miles wide trending southwestward beginning a few miles southwest of Idaho Falls. This strip is bounded on the southeast by fully occupied and developed lands, and on the northwest by lands too high to be reached by any feasible gravity diversion of surface water for recharge. However, within the strip remaining are many square miles that apparently are ideally suited for artificial recharge.

In addition to recharge possibilities in the basalt, gravel deposits adjacent to the Snake River could be used for recharging.

### Geologic features

Except for the southeastern corner, the entire area is underlain by basalt of the Snake River Group and alluvial deposits which together comprise the Snake Plain aquifer. The southeastern corner, southeast of alluvial valley of the Snake River, is underlain by a varied assemblage of older volcanic rocks, whose only significance in this investigation is that they have a much lower permeability than that of the Snake Plain aquifer, and therefore form a negative hydraulic or barrier boundary.

Alluvial deposits about 40 to 130 feet thick overlie the basalt of the Snake River Group in a strip 5 to 10 miles wide along the Snake River. Basalt is exposed only at a few places in this strip, where the Snake River has cut through the alluvium into underlying knobs or ridges of basalt as at Idaho Falls and Woodville. Southwest of Moreland, on a terrace parallel to the Snake River, alluvial sand and gravel fill depressions in what must have been a very irregular basalt surface. Generally the sand and gravel is not more than a few tens of feet thick and is of limited extent. Basalt crops through at many places.

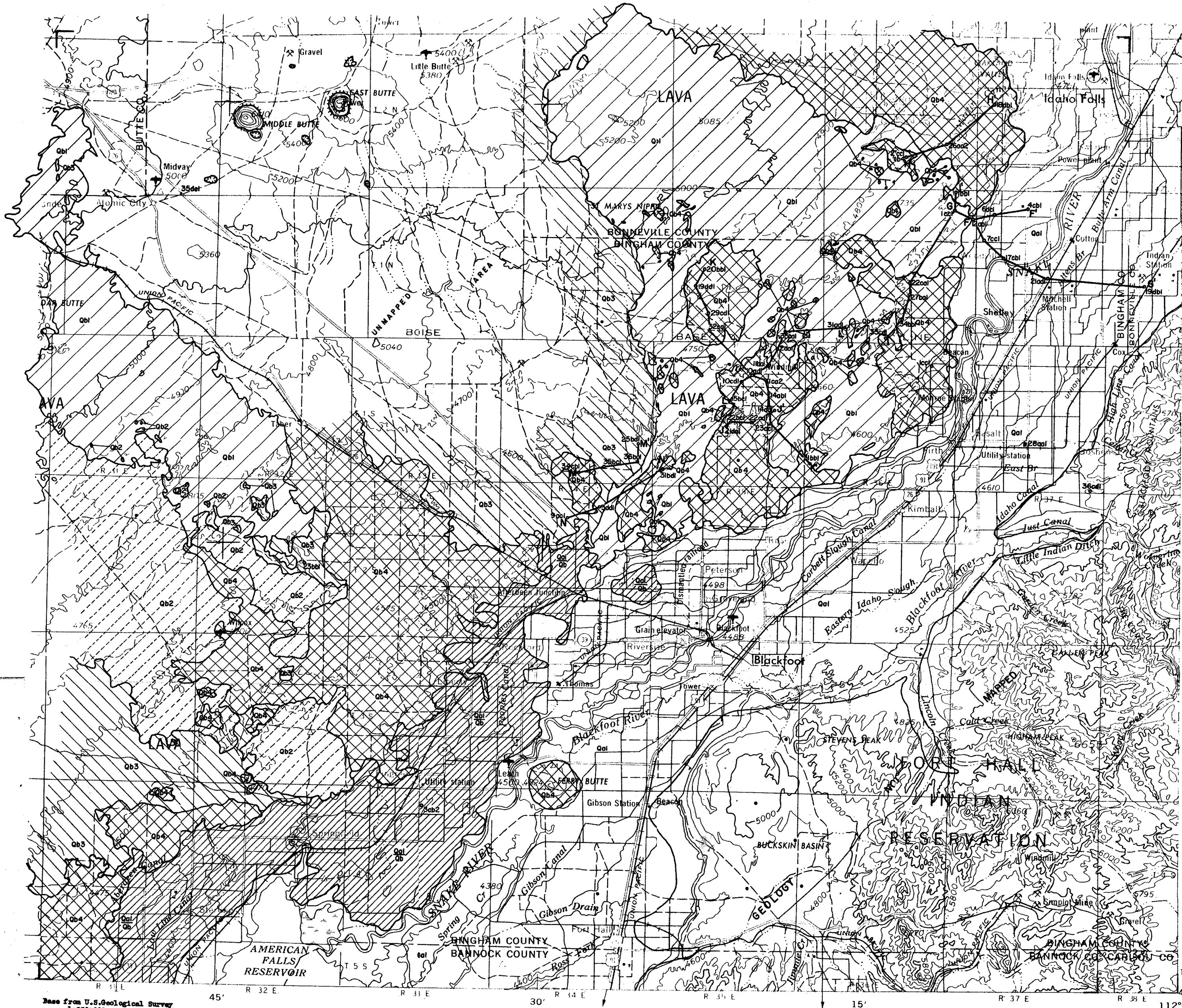
Basalt overlain by varying amounts of windblown silt and playa deposits occupies the northwestern half to two-thirds of the area. The exposed basalt flows were extruded during many different periods of volcanism, probably all in the Quaternary Period. In general, the oldest flows have the greatest thickness of overburden and the youngest have the least. For this study, however, age is relatively unimportant of itself, and the lavas have been separated into four groups on the basis of thickness and continuity of overburden. Basalt shown on the map with the symbol $Qb_4$ is overlain by moderately thick (5 to 15 feet) and continuous deposits of silt and is farmed at many places. Units shown as $Qb_3$, $Qb_2$, and $Qb_1$ have successively lesser amounts of overburden; $Qb_1$ is essentially bare (fig. 26).

Northwest of the Snake River alluvial deposits intertongue with basalt flows at depth. The alluvial deposits lens out toward the northwest and a few miles from the river the only sedimentary materials interbedded with the basalt are occasional layers of fine sand and silt which were deposited in the playas or as windblown deposits (figs. 27, 28, and 29).

## Ground-water features

The basalt of the Snake River Group, and alluvial sand and gravel together comprise the Snake Plain aquifer in the Idaho Falls area. Recharge to the aquifer is by percolation from Snake River and from irrigation, as shown by the water table and flow-net map, figure 3. The importance of irrigation to recharge is shown by the pronounced rise in the water table, generally 15 to 30 feet, each spring after irrigation begins (fig. 30). Flowlines indicate that the water is moving westward beneath most of the area of recharge, but turns southwestward a few miles west of the Snake River, and much of the water discharges into the reach of the Snake River between Blackfoot and American Falls, as described in a previous section of the report.

The depth to water through the irrigated area (the recharge area) generally is 50 to 150 feet. Westward, as the land surface rises, and the water table declines, the depth to water is progressively greater. There apparently are local perched aquifers at a few places, but no extensive perched aquifer has developed as is found in the Egin Bench-Lower Teton River area.




**EXPLANATION**

QUATERNARY

Mostly farmed, generally not suitable for artificial recharge, except locally.

Qal — Alluvial deposits. Sand and gravel in Snake River Valley

Qal/Qb — Discontinuous alluvial deposits overlying basalt which is exposed at many places

Qb4 — Basalt overlain by moderately thick deposits of silt (several to about 15 feet thick at most places)

Mostly not farmed, generally suitable as sites for artificial recharge

Qb3 — Basalt overlain by thin (a few inches to a few feet) deposits of silt

Qb2 — Basalt overlain by very thin, discontinuous windblown silt deposits

Qb1 — Basalt with no overburden

M——M' Geologic section

9ccl Well and number

Contact

Crater

Butte

—4800— Land-surface contour. Contour interval is 200 feet. Intermediate contours are dashed

Scale 0 1 2 3 4 5 Miles

Figure 25.—Map of Idaho Falls area showing geologic features relating to recharge feasibility.

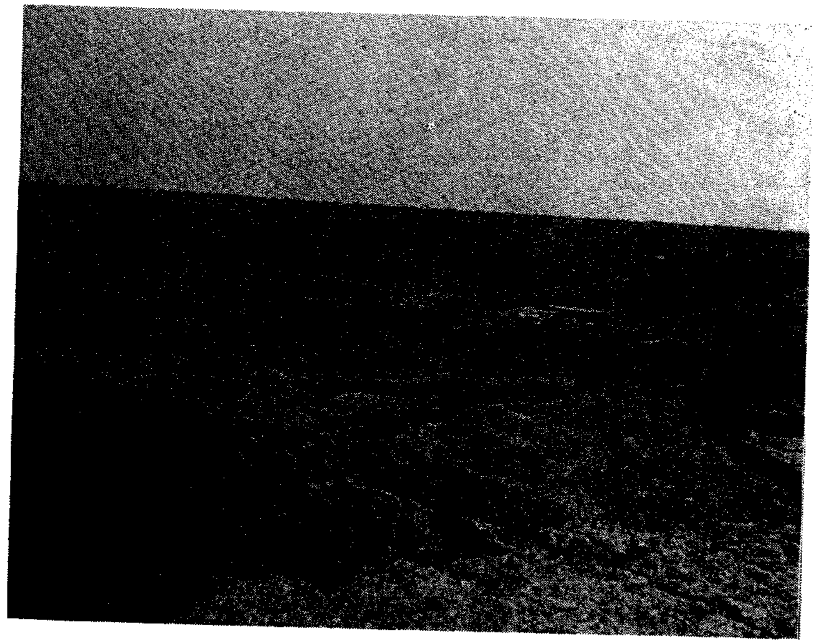


Figure 26.--Basalt surface near the southeast corner of section 33, T. 1 N., R. 35 E.

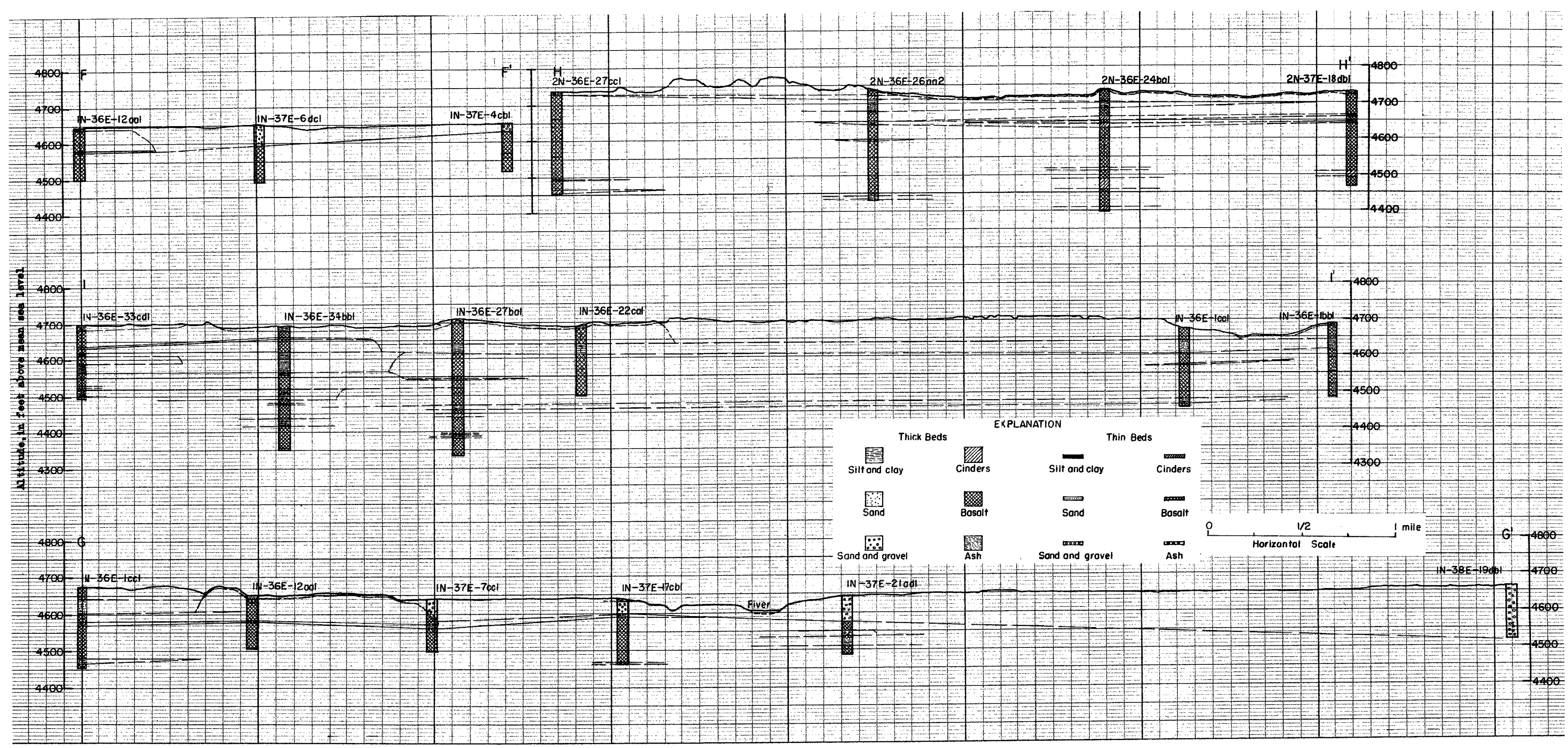



Figure 27.—Geologic sections F-F', G-G', H-H', and I-I', in area west of Idaho Falls.

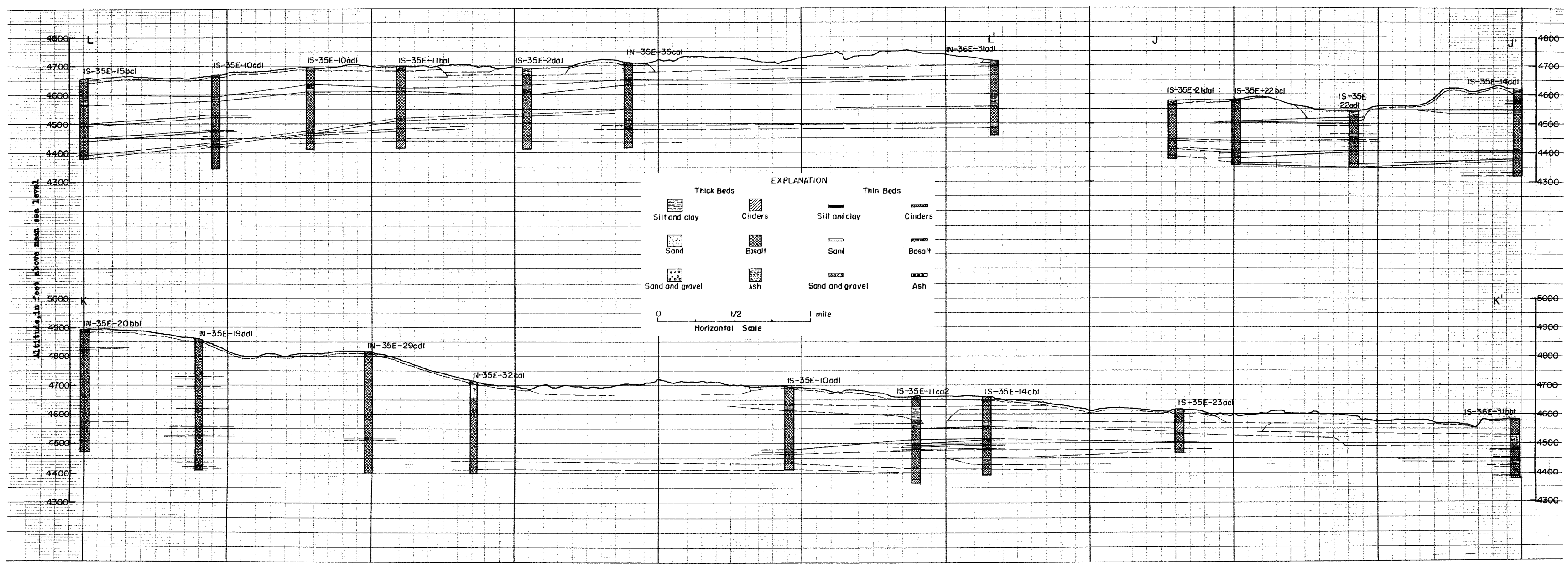



Figure 28.--Geologic sections J-J', K-K', and L-L', in area west of Shelley.

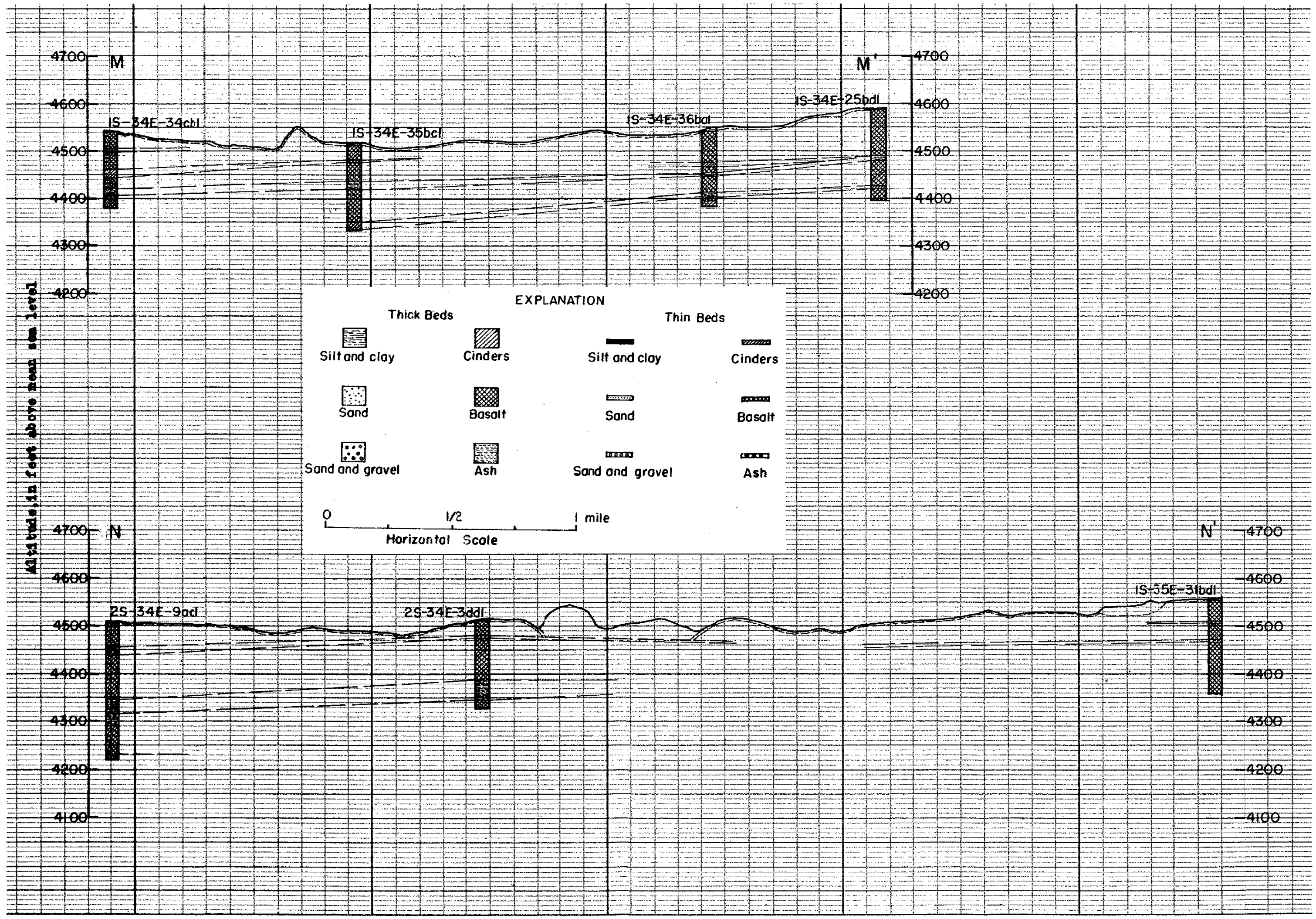



Figure 29.--Geologic sections M-M' and N-N', in area north of Moreland.

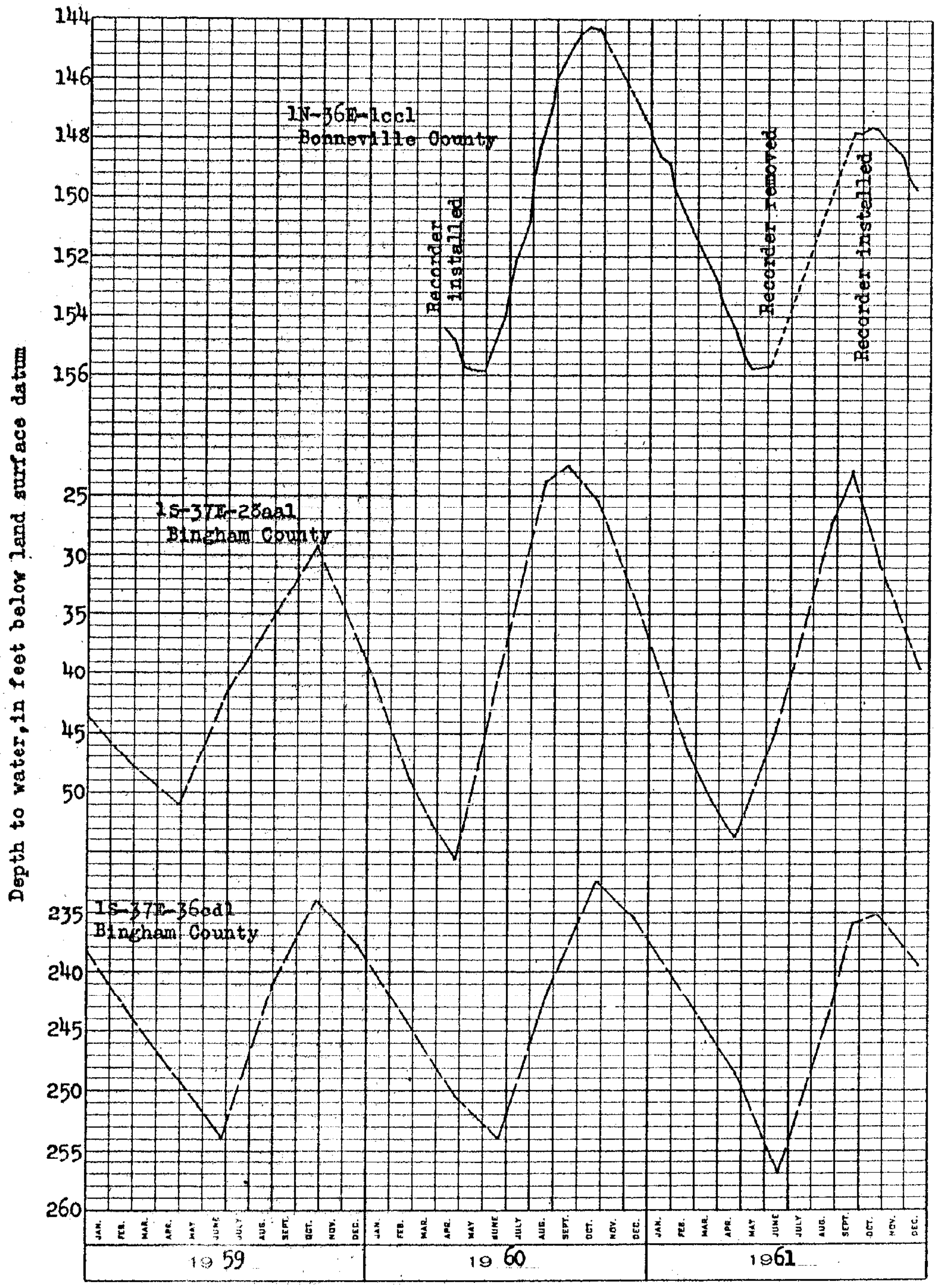



Figure 30.--Hydrographs of wells in the Idaho Falls area.

Underflow in this section of the Snake Plain aquifer is large. According to the flow net (fig. 3) underflow ranges from about 100 to 150 c.f.s. per mile of aquifer width with a hydraulic gradient 4 to 8 feet per mile.

## Source of water and topographic features

The only feasible source of water for artificial recharge is the Snake River. Availability of surplus water from the Snake River was summarized on page 11. For the purposes of this study it was assumed that the maximum diversion would be 120,000 acre-feet a month.

Water could be diverted from the Snake River at some point downstream from its junction with Henrys Fork, which is at an altitude of 4,800 feet.

Studies by the U. S. Bureau of Reclamation (written communication August 1961) indicate that the most feasible diversion downstream from the junction is near or at the diversion for the Great Western Canal, about 6 miles south of Roberts. This diversion is at an altitude of 4,755 to 4,760 feet. Water could be conveyed in a canal from this point to the lava flows west of Idaho Falls. Detailed topographic maps are not available for all of the area but study of the maps that are available indicate that there is 50 to 75 square miles of bare lava surface below the 4,750 contour between Idaho Falls and Blackfoot.

## TW-10 pump recharge test

A recharge test was made at a location 9 miles southwest of Idaho Falls in June and July 1961.

Well 1N-36E-1cc1 (TW-10) drilled as a test well for the U. S. Bureau of Reclamation in 1958, on public domain, was used as a source of water. There is no silt overlying the basalt at this location, and the water was discharged into a crevice in the basalt about 60 feet southeast of the well (see fig. 31).

The uppermost basalt unit is about 36 feet thick at this site. It is separated from the basalt which is the aquifer by about 34 feet of fine silt and sand (fig. 27). The water table is about 150 feet below land surface.

Five holes were drilled to the top of the second basalt primarily to serve as observation wells for the perched aquifer that was presumed would develop when recharge began. The observation well, 1N-36E-2dd1 (OW-10) which was drilled in 1958 along with TW-10, was plugged at the top of the second basalt so that it could also be used for observations on the postulated perched aquifer. Geologic sections through all the holes are shown in figure 32. Data on the wells and core drill holes are given in the table on the following page.

| Well or Core-Drill Hole | Altitude of | | | Thickness of | | Total Depth |
|---|---|---|---|---|---|---|
| | Land Surface 1/ | Top of Silt | Top of Second Basalt | Upper Basalt | Silt | |
| TW-10 (1N-36E-1cc1) | 4,674.05 | 4,638.0 | 4,602.0 | 36 | 36 | 218 |
| OW-10 (1N-36E-2dd1) | 4,675.07 | 4,640.0 | 4,603.0 | 35 | 37 | 215 |
| D.H. 1 | 4,674.82 | 4,639.5 | 4,603.1 | 35.3 | 36.4 | 71.7 |
| D.H. 2 | 4,674.95 | 4,639.35 | 4,603.45 | 35.6 | 35.9 | 71.5 |
| D.H. 3 | 4,674.09 | 4,638.0 | 4,597.1 | 36.1 | 40.9 | 77.0 |
| D.H. 4 | 4,673.46 | 4,637.8 | 4,614.5 | 35.7 | 23.3 | 59.0 |
| D.H. 5 | 4,675.72 | 4,638.9 | 4,610.1 | 36.8 | 28.8 | 66.9 |
| Average | | | | 35.8 | 34.0 | |

1/ Land surface is top of uppermost basalt at all holes.

Pumping began at 5 P.M. on June 9 at a rate of 2,400-2,500 g.p.m. with a drawdown of 0.7-0.8 foot. Pumping was nearly continuous until June 19. Breakdown of equipment forced a complete suspension of pumping from June 20 to July 7, and pumping was intermittent from July 7-12. Pumping was nearly continuous from July 13 to August 1, when the test was terminated. A total of about 362 acre-feet was pumped during the test.

During pumping the main water table rose a total of more than 3 feet because of recharge from irrigation on nearby lands. Pumpage is shown graphically in figure 33.

The water was disposed of in a crevice in the basalt (fig. 34) and at no time was there any ponding of water at the surface. However, a perched water table did develop in and on top of the main sedimentary interbed. Hydrographs of this perched water table and its relation to the top of the silt layer are shown in figures 35-40.

The perched water table reached its maximum height in most wells near the end of the test. The maximum height of water above the t op of the silt in each well was as follows:

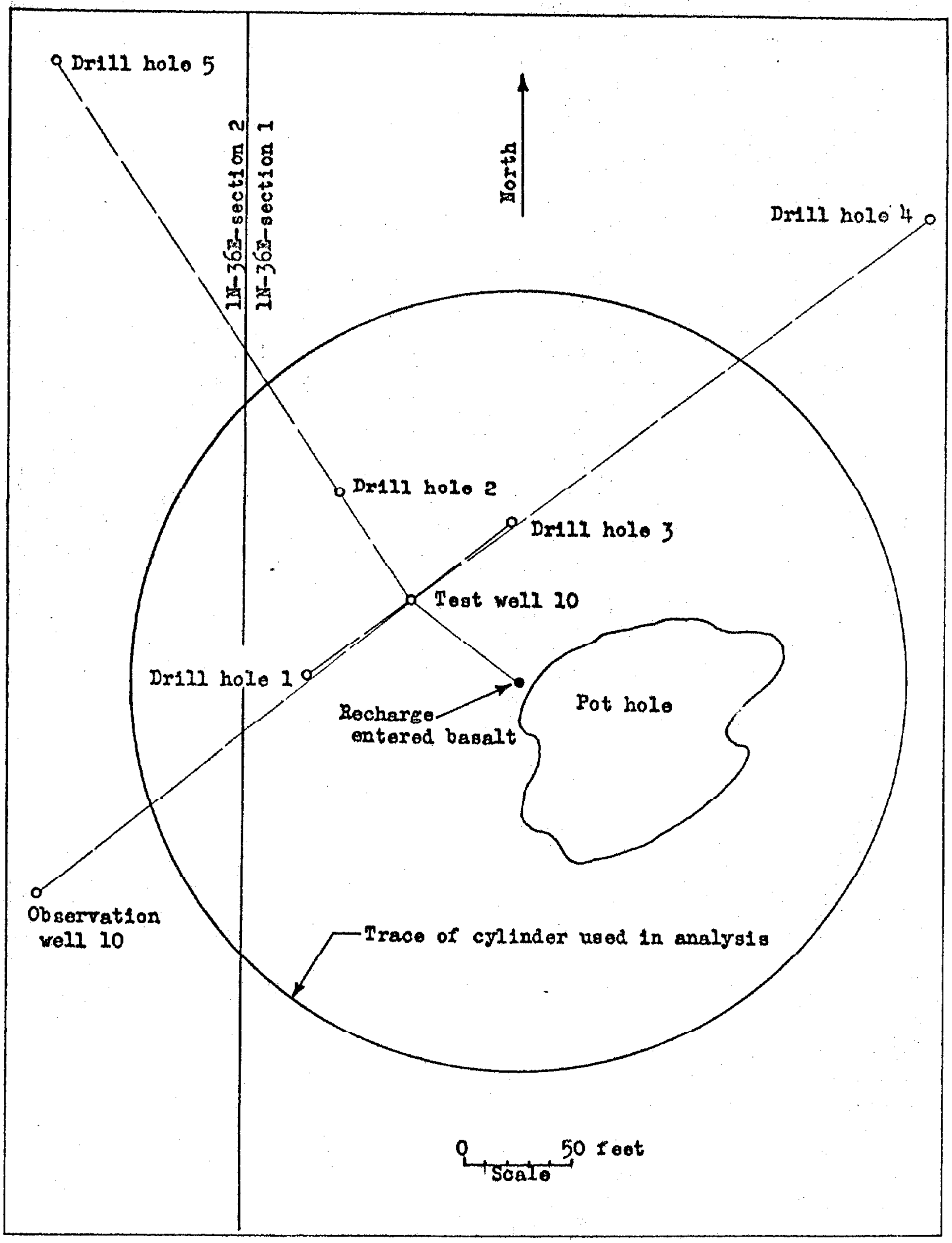



Figure 31.--Map of TW-10 pump-recharge test site

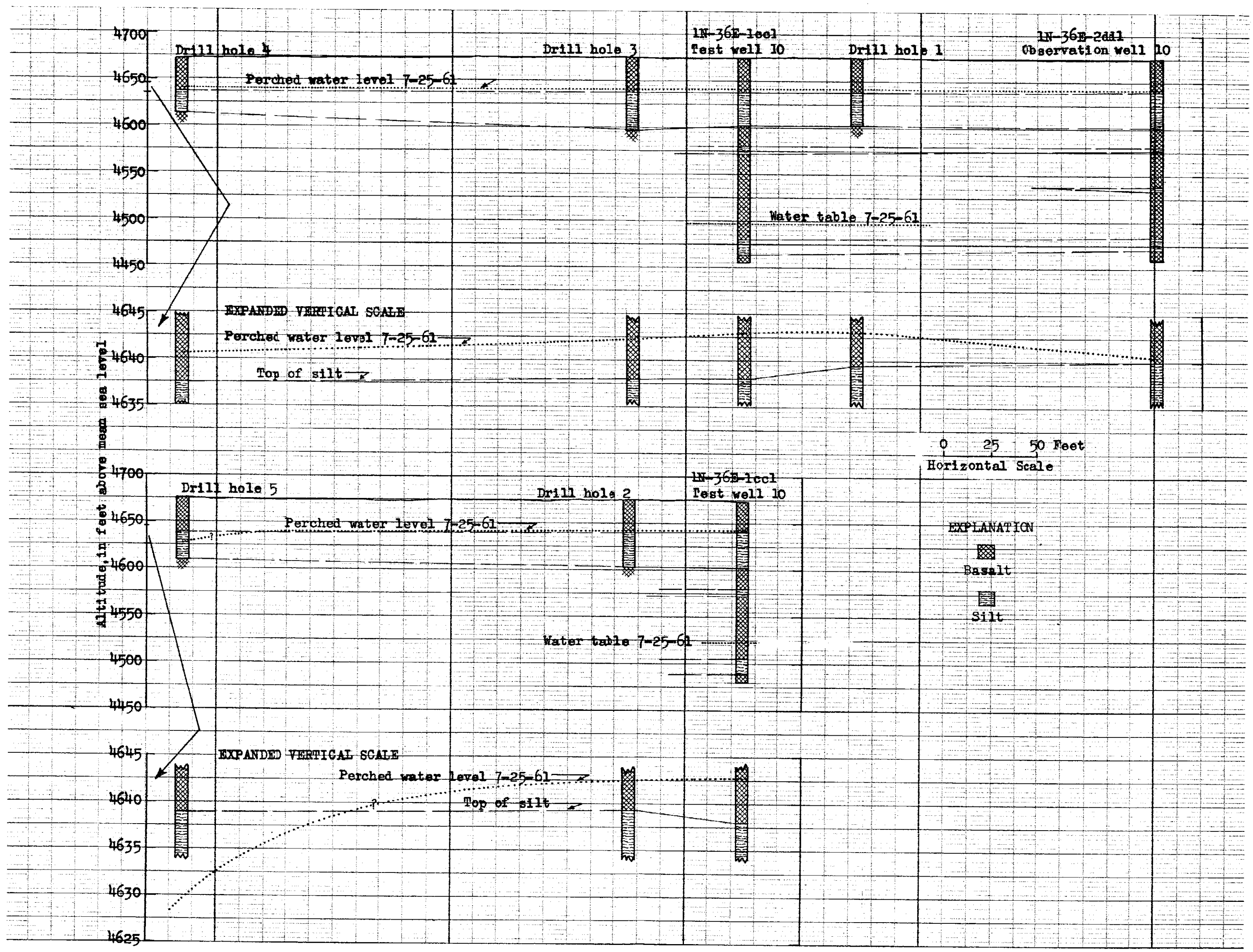



Figure 32.--Geologic sections through wells and core-drill holes in the TW-10 recharge test area.

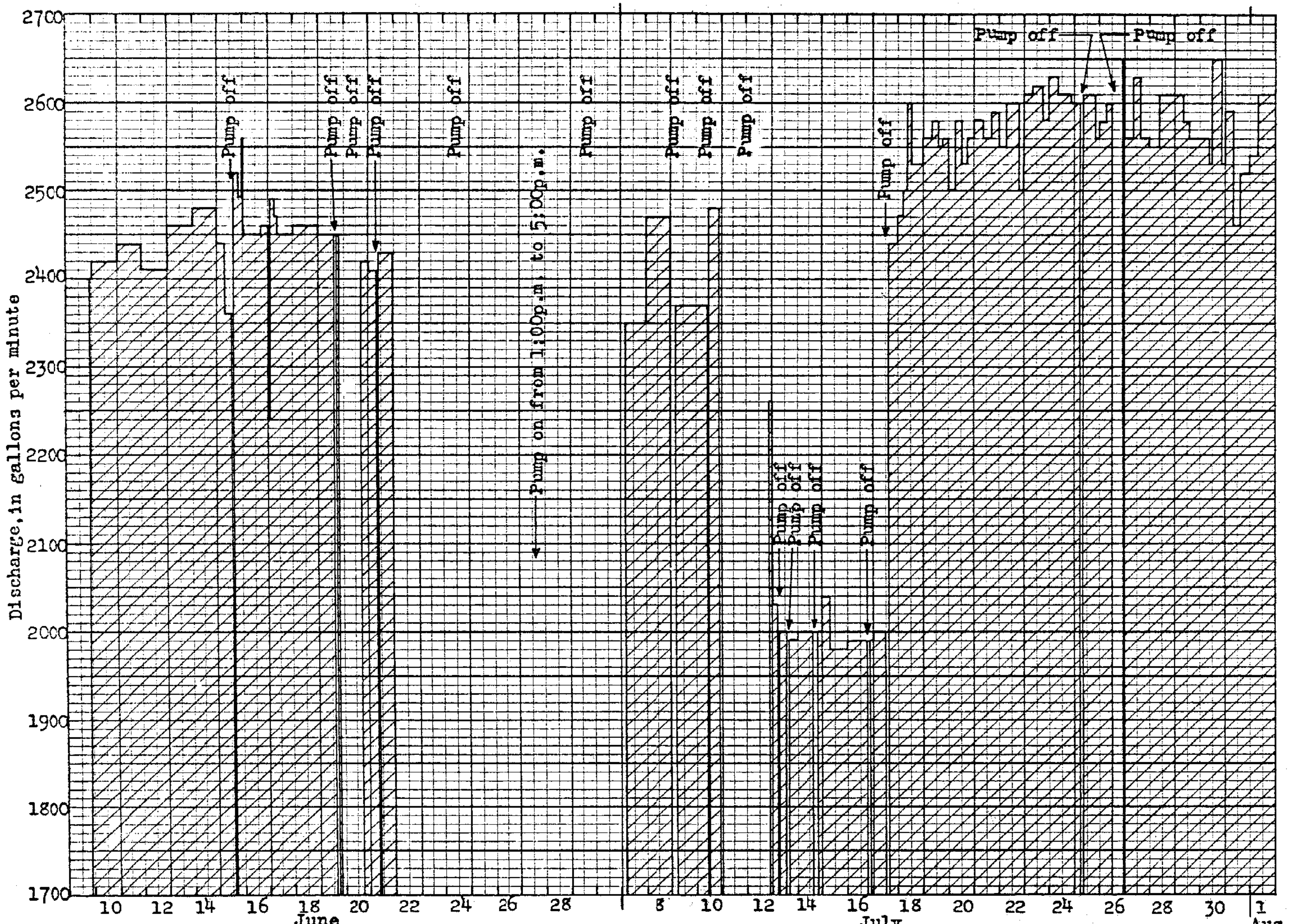



Figure 33.—Graph showing water pumped for recharge at TW-10 site.

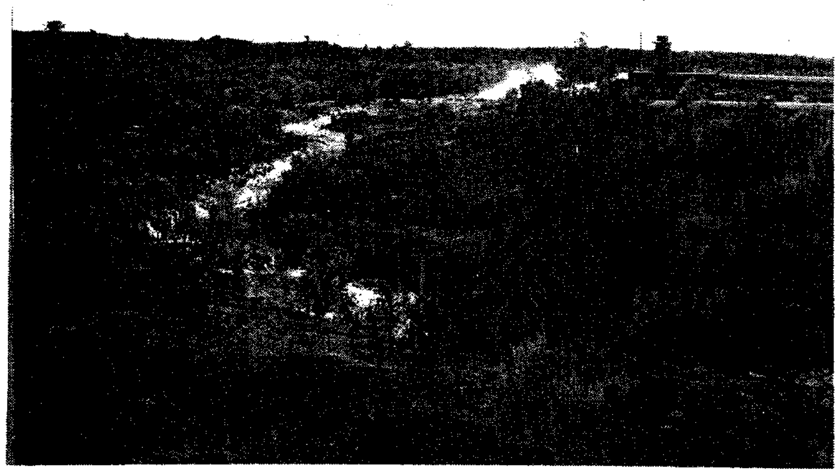


Figure 34.--View at site of TW-10 pump-recharge test.

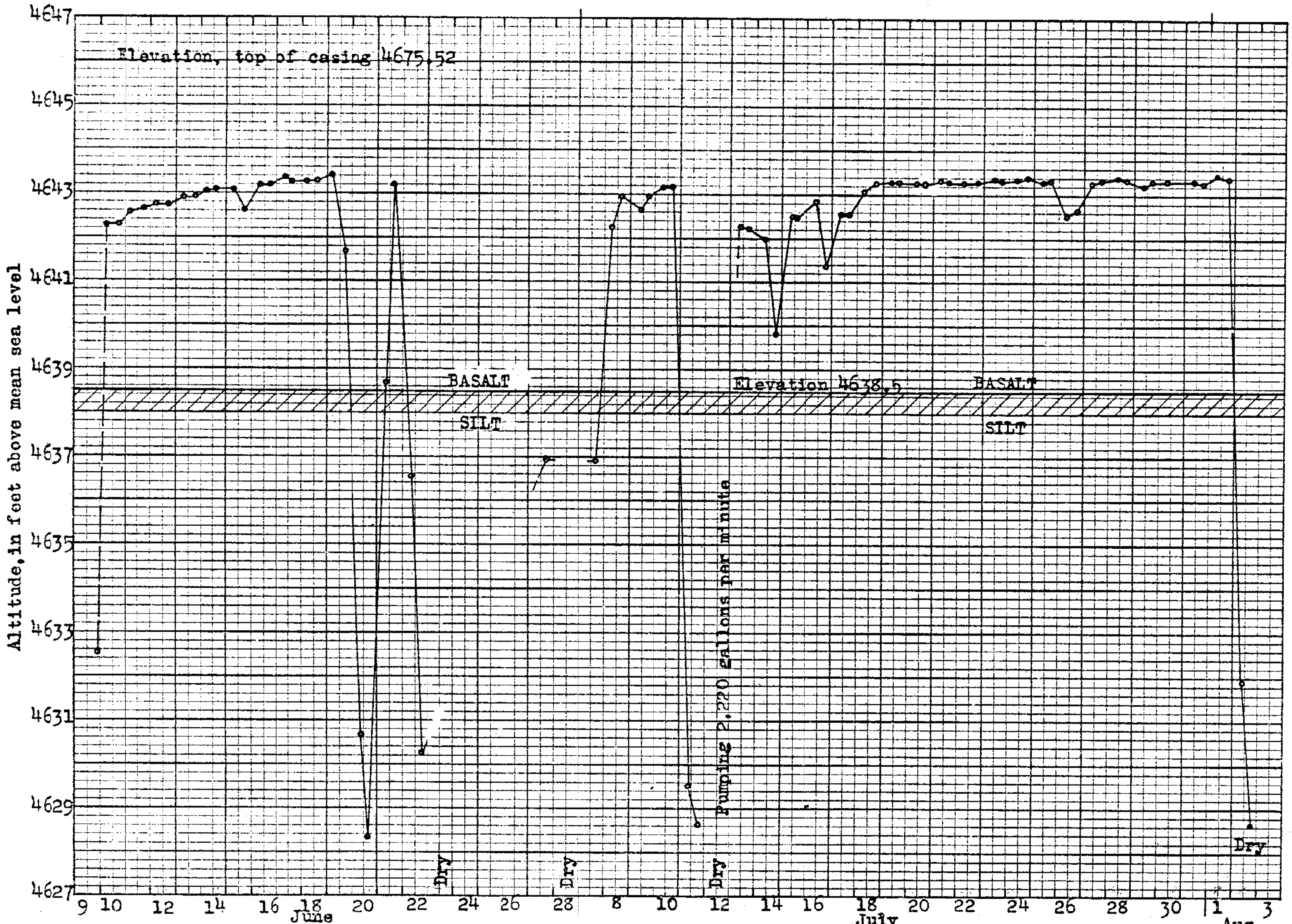



Figure 35.--Hydrograph of drill hole 1, June 9-August 2, 1961.


Figure 36.—Hydrograph of drill hole 2, June 9-August 2, 1961.

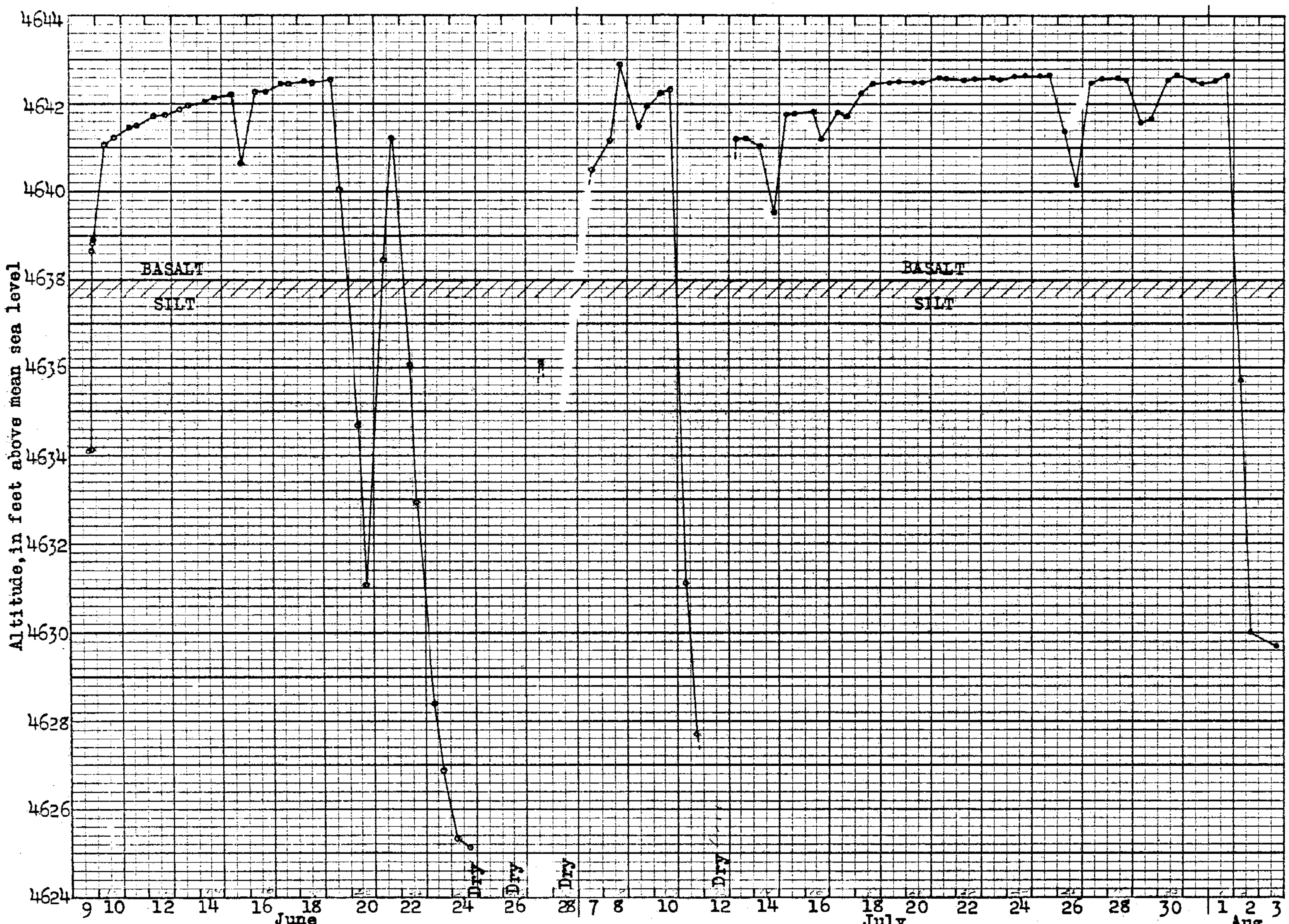



Figure 37.--Hydrograph of drill hole 3, June 9-August 2, 1961.


Figure 38.--Hydrograph of drill hole 4, June 9-August 2, 1961.

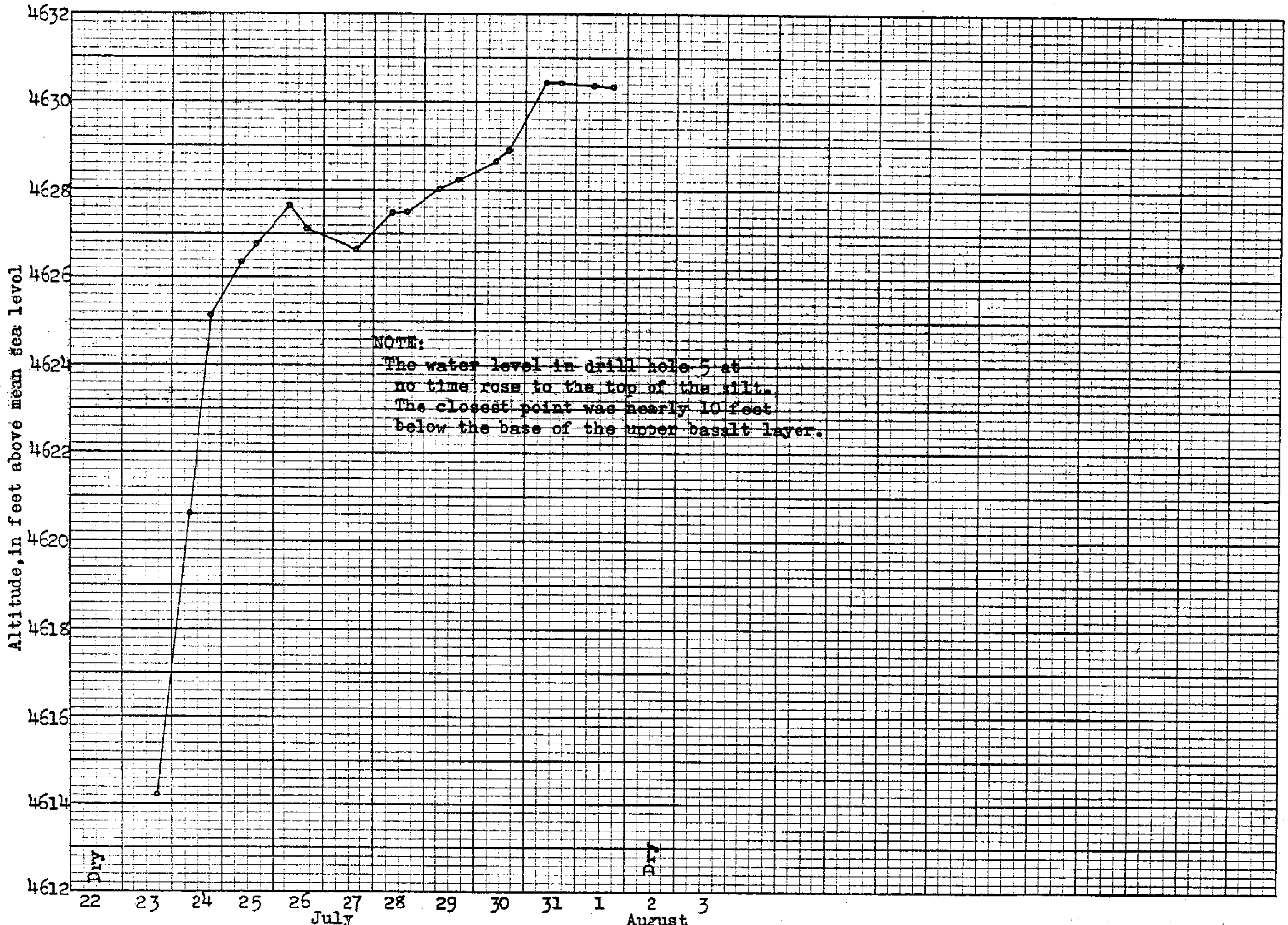



Figure 39.--Hydrograph of drill hole 5, June 9-August 2, 1961.

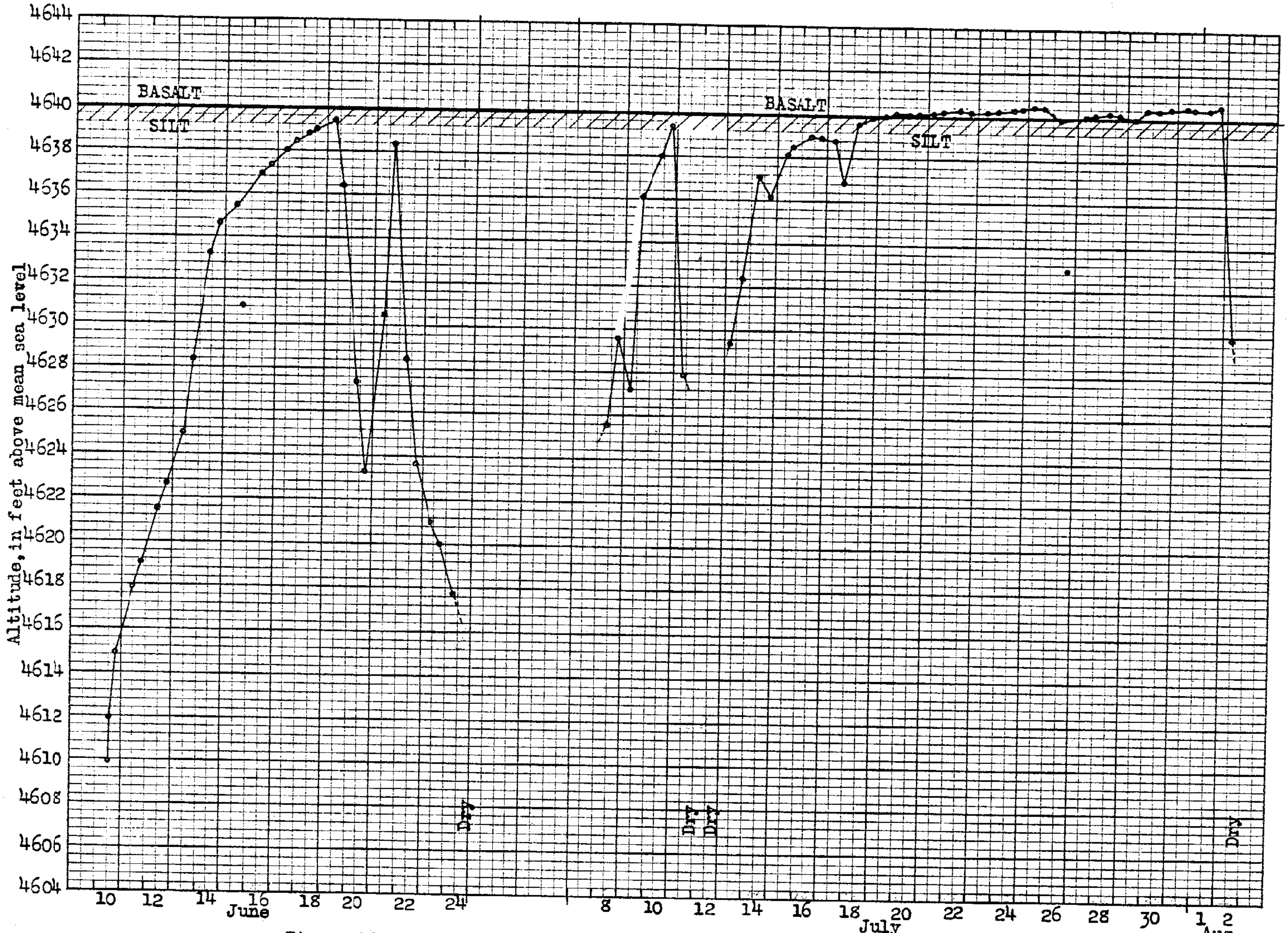



Figure 40.--Hydrograph of well OW-10 (1N-36E-2dd1), June 9-August 2, 1961.

| Well | Maximum Height | Well | Maximum Height |
|---|---|---|---|
| DH 1 | 4.9 | DH 4 | 3.1 |
| DH 2 | 3.6 | DH 5 | 0 |
| DH 3 | 4.7 | OW-10 | 0.5 |

After recharge ceased the water level in all holes dropped below the top of the silt in less than a day, and in most holes probably within a few hours.

The salient points regarding this recharge experiment may be stated as follows:

A perched water table developed in the silt layer, and this water table rose into the basalt.

The water table rose rapidly into the base of the upper basalt, and then rose gradually as pumping continued. Whenever recharge ceased, the water level dropped below the base of the basalt within a few hours. The perched water table had rather steep slopes away from the point of recharge (fig. 33).

The results shown by the test are interpreted as follows:

The pore space in the silty layer contained considerable water before recharge began, it probably was not far below saturation. There is no soil covering the basalt in this area and much of the 7 to 9 inches of annual precipitation runs into crevices and percolates down into the silt. The basalt layer below is porous and water from the fine-grained layer above will not enter the basalt until there is a positive pressure on the water, that is until the hydrostatic head exceeds one atmosphere. Thus the silt is near saturation at all times, addition of a very small amount of water at the top of the layer results in a very rapidly rising water table. In a sense, the water table actually was perched on the base of the silt.

When recharge began, the water table rose rapidly to the top of the silt; because the base of a single basalt flow overlying silt is not very permeable, the water level at first rose rather rapidly in the basalt. Thereafter it rose more slowly, reaching a level where the gradient was sufficient to move the water away from the point of recharge as rapidly as it was added. Water could be discharged by lateral outflow or by vertical percolation through the silt down to the main water table or by a combination of the two processes. The relative proportions of these two components of outflow are in question.

For the following reasons it is believed that most of the water moved down through the silt.

The mound of water in the basalt extended laterally only about 200 feet in the direction of D.H. 5, and barely reached OW-10, 250 feet away. The extent of the cone beyond D.H. 4 is not known but considering the gradient between D.H. 3 and D.H. 4, it probably was not more than about 300, for total distance of 600 feet from the crevice into which the water disappeared. The spread of the mound obtained by averaging the spread in the three directions was about 375 feet. Thus, the average diameter of the mound in the basalt probably did not exceed 750 feet. The average slope of the ground-water mound between the near and the far drill holes was 1.3 feet per 100 feet (.013 feet per foot). A circle, described around the crevice where recharge entered the basalt, with a radius of about 180 feet roughly bisects the average distance between the near and far drill holes. The average saturated thickness of basalt on July 25 at this radial distance, near the end of the test, was 2.8 feet. The equation Q = PIA, where Q is the quantity of water in gallons a day per square foot, I is the hydraulic gradient in feet per foot, and A is the cross sectional area in square feet, can be used to solve for permeability of the basalt, assuming that none of the recharged water seeps from the basalt within the area of the circle. Solving, $P = \frac{Q}{IA} = \frac{3.6 \times 10^6}{.013 \times 3{,}170} = 87{,}500$ g.p.d. per square foot. The flow across the boundary circle would be decreased by the amount of downward seepage from the basalt within the circle, and the permeability of the basalt would be correspondingly less than the figure derived.

As shown by the hydrographs of drill holes 1, 2, 3, and 4 (figs. 35, 36, 37, and 38) the water table rose rather gradually, but dropped abruptly entirely below the base of the basalt within a short time after recharge ceased. This abrupt decline is not compatible with the decay of a ground-water mound by lateral outflow but is the result to be expected of downward leakage through a semipermeable layer. If it is assumed that all the water percolated through the silty layer within an area 750 feet in diameter, the seepage rate would be about 1 foot per day.

Not much information is available regarding infiltration rates through silty sediments in the Snake River Plain. Infiltration measurements in the beds of the Big Lost River playas showed infiltration rates ranging from 0.4 to 5.4 and averaging 2.3 g.p.d. per square foot (Nace and others, 1959). These playa sediments probably are similar, but may be more permeable than the silty interbed at the TW-10 site.

Laboratory tests made on 7 samples of material from the silty layer at the TW-10 site indicate a permeability ranging from practically nil to 2 g.p.d. per square foot and averaging about 0.7 g.p.d. per square foot, equivalent to a percolation rate of slightly more than 0.1 acre-foot per acre per day. It may be that the silty layer is considerably more permeable at some places than at others; also, there may be thin spots or places where the layer is missing and the upper basalt is in contact with the lower basalt. Whatever the exact situation, most of the water recharged probably moved out of the upper basalt layer by vertical percolation.

### Summary of recharge possibilities in the basalt

Conclusions as to the feasibility of recharge by spreading water on the basalt in this area cannot be based entirely upon the results of such a small-scale test as was made at the site of well TW-10. The intake capacity of the upper basalt flow apparently is almost unlimited; however, if the silty layer will transmit water to the main water table at a rate of only 1 acre-foot per acre per day, then a thousand acres would be required for recharge of a thousand acre-feet per day.

However, as shown by many well logs, and illustrated on the geologic sections I-I' and L-L' in figures 27 and 28, the sedimentary interbeds pinch out to the west and northwest, away from the Snake River. The location of the recharge test, less than one-half mile from the edge of the upper basalt flow, was not at a favorable location with respect to underlying sedimentary strata. As the water is conducted westward, from depression to depression on the basalt, conditions for vertical seepage should improve and the rates might be manyfold larger within a few miles.

### Recharge of gravels adjacent to the Snake River

The Snake River loses water from its channel throughout the reach from Roberts to Blackfoot. The alluvial deposits along this reach could be used for recharge of additional water by diversions to abandoned channels, unused gravel pits and similar depressions. Through most of the reach the water table is 50 to more than 100 feet below land surface so that a large storage space is available above the water table. Basalt protrudes through the alluvial deposits at a few places; elsewhere the gravel deposits range from a few to more than 100 feet in thickness. Well logs indicate generally a fairly continuous sequence of gravelly deposits; rarely are there reports of sandy or silty intervals.

No quantitative information is available on the intake capacity of the gravel deposits, however, the gravel generally appears to be clean, coarse, and permeable.

Rates of percolation from the channel of the Big Lost River, in downstream reaches on the National Reactor Testing Station, about 60 miles west of Idaho Falls, were measured in 1951 to 1953 (Nace and others, 1959, p. 21-30). Rates ranged from about 0.3 to 2.5 and averaged 1.0 foot per day. The rates measured varied almost directly with discharge. Big Lost River is intermittent, and has a low gradient through the reach. The alluvium along the Snake River probably is considerably more permeable than along this reach of Big Lost River. Also, the depth of water would be considerably greater in gravel pits than in the shallow channel of Big Lost River, and infiltration rates would be greater because of the greater head.

At Peoria, Illinois, rates ranged from about 40 to 100 feet a day in two pits operated by the State Water Survey for three recharge seasons (Suter and Harmeson, 1960, p. 45).

Percolation rates in the gravels along the Snake River probably would be in the range of 5 to 50 feet per day. Quantitative tests would be required to derive a more precise value.

### Probable effects of large-scale recharge in the area

By assuming aquifer coefficients, and making some simplifying assumptions regarding boundaries, the effect on the aquifer of adding large amounts of water by artificial recharge can be estimated.

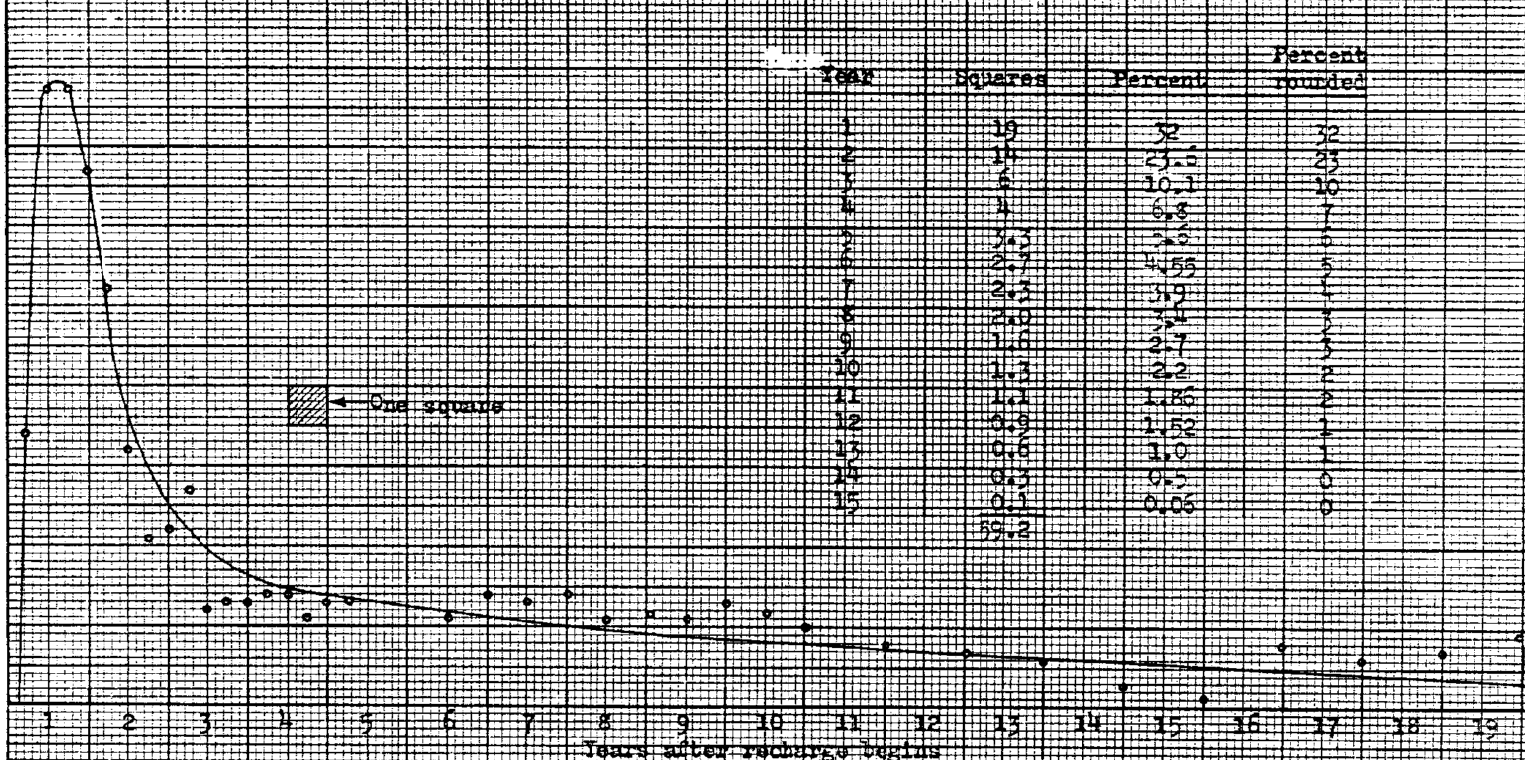
The average coefficient of transmissibility is assumed to be $2 \times 10^7$ gallons a day per foot; the coefficient of storage is assumed to be 0.10. A positive boundary at right angles to the flowlines is idealized near the upper end of the discharge reach between the mouth of the Blackfoot River and American Falls. Point of recharge is assumed to be 27.5 miles upgradient from this positive boundary. All other boundaries were disregarded, the only other near boundary is a negative one parallel to the flowlines. Recharge is assumed to be at a constant rate for a period of 6 months.

With the above assumed coefficients and simplified boundary conditions, the head change was computed for a point 2.5 miles upgradient from the positive boundary (fig. 41). This figure indicates that under the assumed conditions, discharge into the American Falls Reservoir reach would begin to increase within a few months after artificial recharge begins and peaks within 2 months after recharge ceases.

Not all the water recharged in the area west of Idaho Falls would return to American Falls Reservoir. Flowlines (fig. 3) show that about 40 percent of the underflow through this section of the aquifer is tributary to the American Falls Reservoir reach, and 60 percent is tributary to the Hagerman Valley reach. Of that part of the water returning in the American Falls Reservoir reach, the percentage that returns each year is approximately shown by the ratio of the area under the curve for the individual year to the total area under the curve. As shown by the table on figure 41, 32 percent of the water returning in the reach discharges within the first year, 23 percent in the second year, and so on.

The above discussion does not mean to imply that the recharged water will physically move to the discharge area within a few months; actual velocity of the water probably is only a mile or two a year. However, the ground-water mound moves outward so that underflow and discharge are increased as shown.

That the calculated rate of spread of the ground-water mound is of the proper magnitude is shown by the spread of the recharge wave from irrigation in the Aberdeen-Springfield area ( see page 17 and figure 7) where the ground-water mound spreads 22 miles in 90 to 105 days.




| Year | Squares | Percent | Percent rounded |
|---|---|---|---|
| 1 | 19 | 32 | 32 |
| 2 | 14 | 23.6 | 23 |
| 3 | 6 | 10.1 | 10 |
| 4 | 4 | 6.8 | 7 |
| 5 | 3.3 | 5.6 | 6 |
| 6 | 2.7 | 4.55 | 5 |
| 7 | 2.3 | 3.9 | 4 |
| 8 | 2.0 | 3.4 | 3 |
| 9 | 1.6 | 2.7 | 3 |
| 10 | 1.3 | 2.2 | 2 |
| 11 | 1.1 | 1.86 | 2 |
| 12 | 0.9 | 1.52 | 1 |
| 13 | 0.6 | 1.0 | 1 |
| 14 | 0.3 | 0.5 | 0 |
| 15 | 0.1 | 0.06 | 0 |
| | 59.2 | | |

Figure 41.--Percent distribution of head changes in the Snake Plain aquifer caused by recharging under assumed conditions in the Idaho Falls area.

## Milner-Shoshone area

The Milner-Shoshone area extends northwestward along the Milner-Gooding canal (fig. 42). The area which would be usable for artificial recharge forms an irregular strip along the canal. Diversion to the canal is at an altitude of about 4,130 feet.

The only topographic map available is the Army Map Service 1:250,000 series with 100- and 200-foot contour intervals so that altitudes are not accurately known. However, that map and air photos show that the land surface rises to the east and northeast so that the area to which water could be diverted on the east side of the canal includes only small parcels immediately adjacent to the canal.

Notch Butte, south of Shoshone, rises above the general land surface and includes perhaps a township which would be too high to be reached by surface diversions. Beginning south of this butte (about 6 miles south of Shoshone), a strip of land 4 to 6 miles wide extending for 10 to 12 miles roughly parallel to the canal, is topographically situated so that it might be reached by water diverted from the canal.

### Geologic features

The entire area between the Snake and Wood Rivers is underlain by basaltic lava flows of the Snake River Group. The basalt was extruded from several centers, chiefly on the east side of the Milner-Gooding Canal. Broad lava domes mark these centers.

The basalt is overlain throughout much of the area by varying amounts of sedimentary materials which accumulated in playas or as wind deposits. Most of the land where the sedimentary deposits are a few feet or more thick and are reasonably extensive, is farmed.

Because the most important surficial characteristic for artificial recharge is the thickness, extent and continuity of overburden, the mapped area was divided into units on that basis. The subdivisions are based almost entirely on interpretation of areal photos. Of the 4 units shown, 2 generally are not suitable for artificial recharge by water spreading. The other two consist of areas too rough for farming, where basalt exposures are numerous and irregular and are separated by thin, discontinuous patches of overburden.

The basalt in this area is interbedded with sedimentary materials, as in the Roberts-Plano and Idaho Falls areas, but there apparently are no thick, extensive sedimentary deposits such as are encountered in some parts of the other two areas. The sedimentary interbeds in the Milner-Shoshone area are chiefly thin lenses of windblown silt, sand and volcanic ash and playa deposits of limited extent. Cinder deposits apparently are common, but because they generally are very permeable, they are an asset rather than a liability to recharge. Subsurface conditions are illustrated in several cross sections in figure 43.

## Ground-water features

The only aquifer in the area between Milner and Shoshone is the basalt and associated pyroclastics of the Snake River Group. The water table ranges from about 150 to 250 feet below the land surface. There are no really significant perched aquifers, but local perched aquifers have been encountered beneath irrigated tracts, and near the canal. The water table slopes slightly south of west with a gradient, near the canal, of about 10 feet per mile. A few miles to the west the gradient increases to about 40 feet per mile. Flowlines (fig. 3) indicate an underflow of about 150 cubic feet per second per mile width of aquifer. The source of this underflow is chiefly at the eastern end of the plain, 100 to 150 miles eastward. However, considerable water is added to the aquifer by leakage from the Milner-Gooding canal and percolation from irrigated farms in the vicinity of Hazelton, Shoshone, and Dietrich. For that reason the water table shows an annual cyclic response to irrigation (fig. 44). These hydrographs also show a continuing downward trend. The longer term trend of the water table in the area is shown by the hydrograph of well 9S-20E-1dal (fig. 45). This curve shows a downward trend beginning in 1954, probably related to pumping in the Minidoka area to the east. The downward trend was accelerated beginning in 1958, probably because of greatly increased withdrawals of ground water in the Hazelton area.

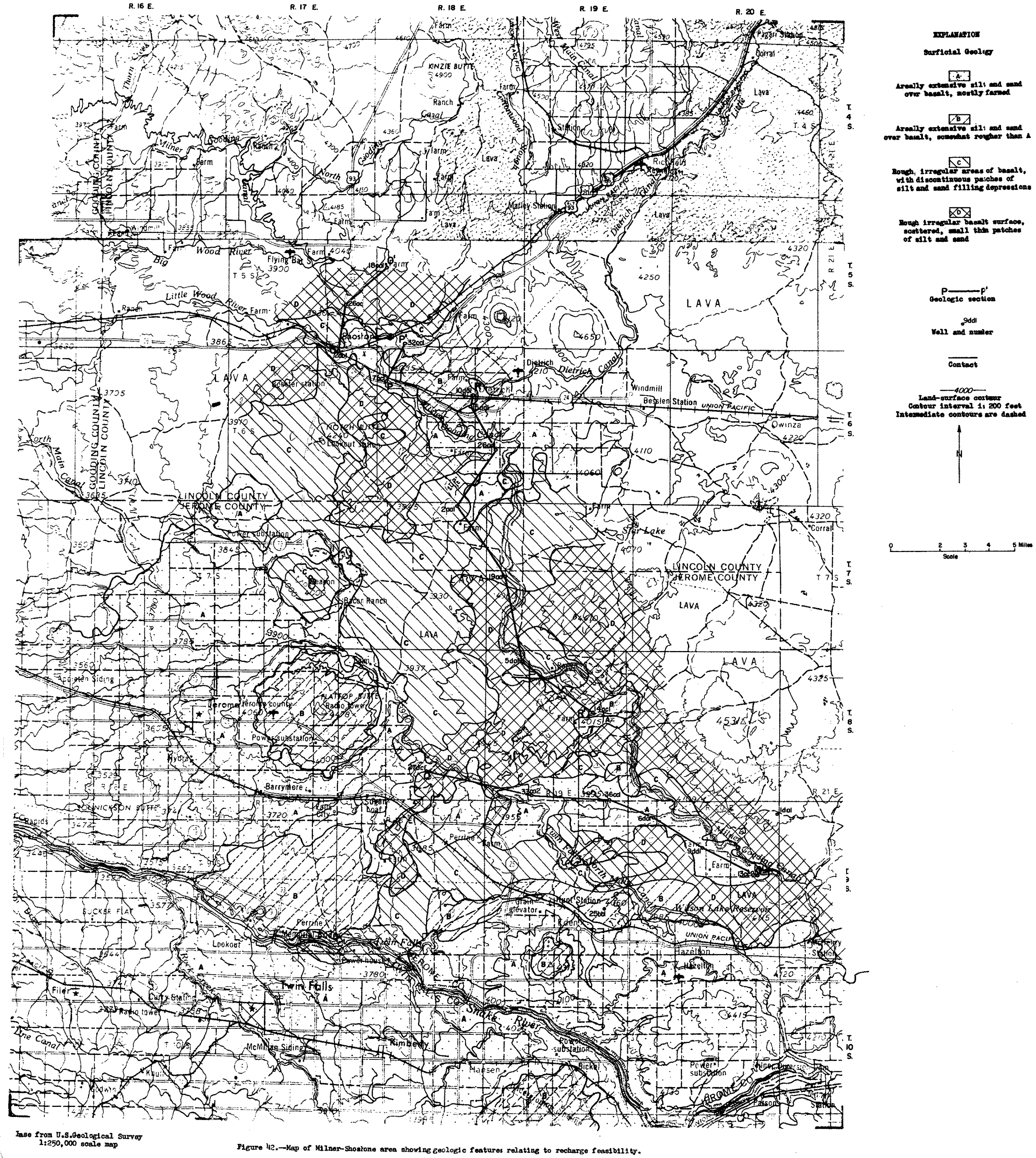
To the west the aquifer terminates in the canyon of the Snake River (Hagerman Valley reach). The base of the aquifer, at the contact with underlying less permeable volcanic rocks generally ranges in altitude between 3,000 and 3,150 feet, 100 to 150 feet above river level. The line of discharge between Twin Falls and Bliss is 25 to 30 miles west of the Milner-Gooding Canal between Milner and Shoshone.

## Summary

Large-scale topographic maps are not available to show potential recharge sites along the Milner-Gooding Canal. The Twin Falls topographic sheet of the United States series at scale of 1:250,000 indicates that areas covering many square miles are favorably situated for recharge by water spreading in the northern two-thirds of township 8S-19E. Closed depressions totaling only a few square miles are shown by the 100-foot contour interval on the map, but undoubtedly there are many more square miles of depressions than are shown. Much of this area is shown by areal photos to be rough surfaced basalt with thin discontinuous patches of silt. Several other areas further north, along the west side of the canal, also appear to be suitable for recharging.

## Probable effects of artificial recharge in the area

The effects of pumping 250 c.f.s. for 122 days on the water table in the Shoshone-Dietrich area was computed in the report by Mundorff and others (1960, p. 185-186). The computations apply equally to buildup of




Base from U.S.Geological Survey
1:250,000 scale map

Figure 42.—Map of Milner-Shoshone area showing geologic features relating to recharge feasibility.

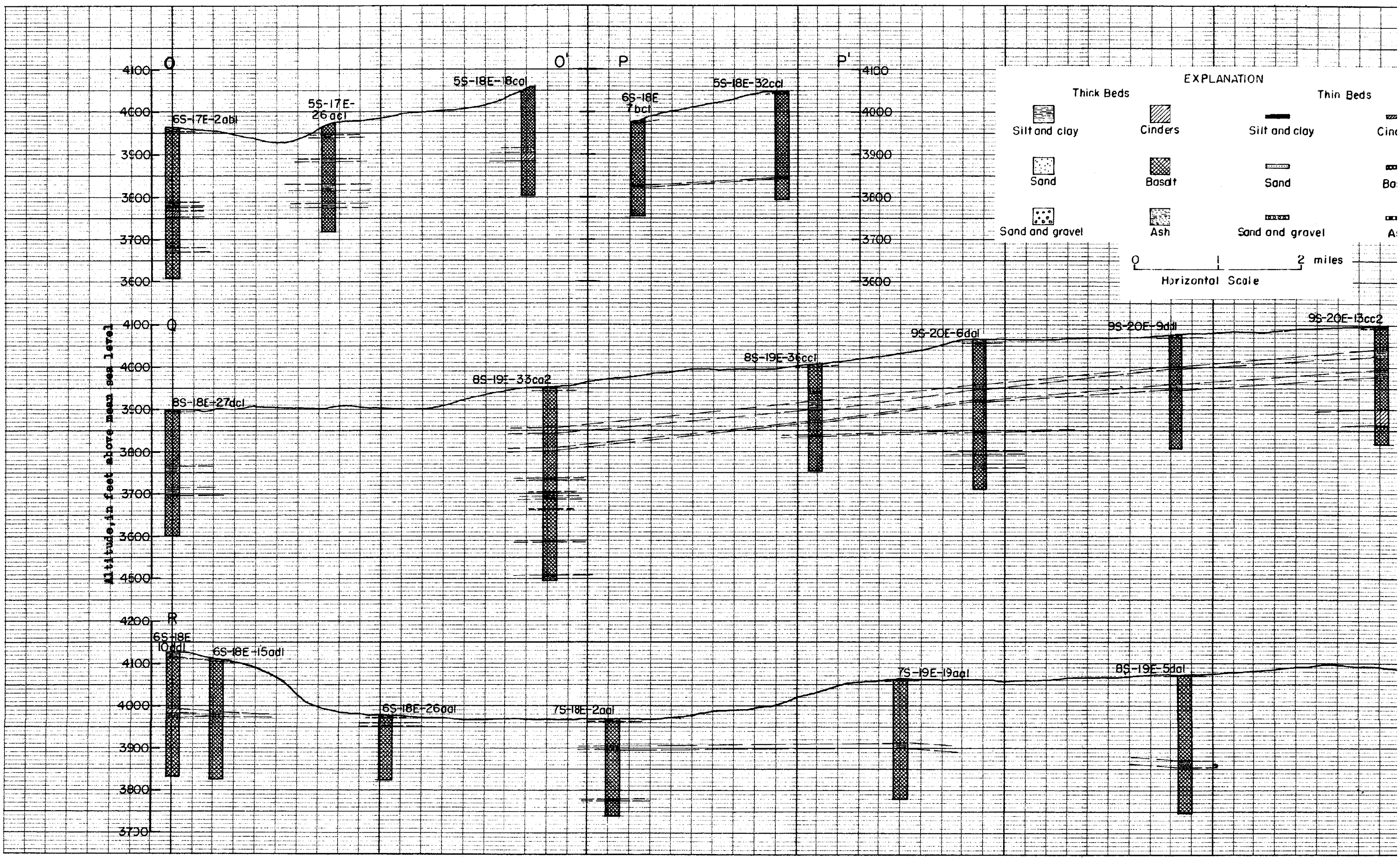



Figure 43.--Geologic sections O-O', P-P', Q-Q', and R-R', in the Milner-Shoshone area.

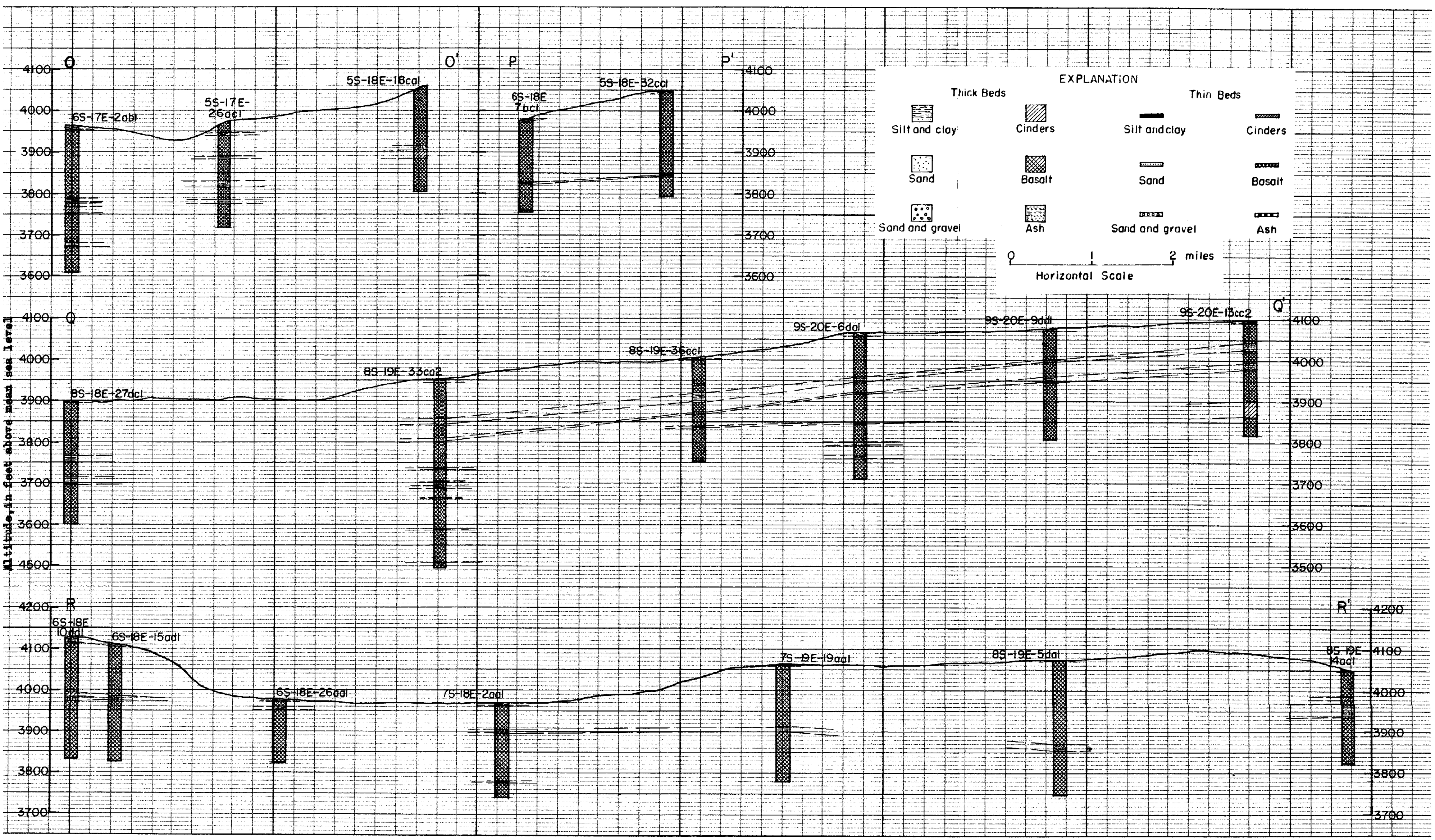



Figure 43.--Geologic sections O-O', P-P', Q-Q', and R-R', in the Milner-Shoshone area.

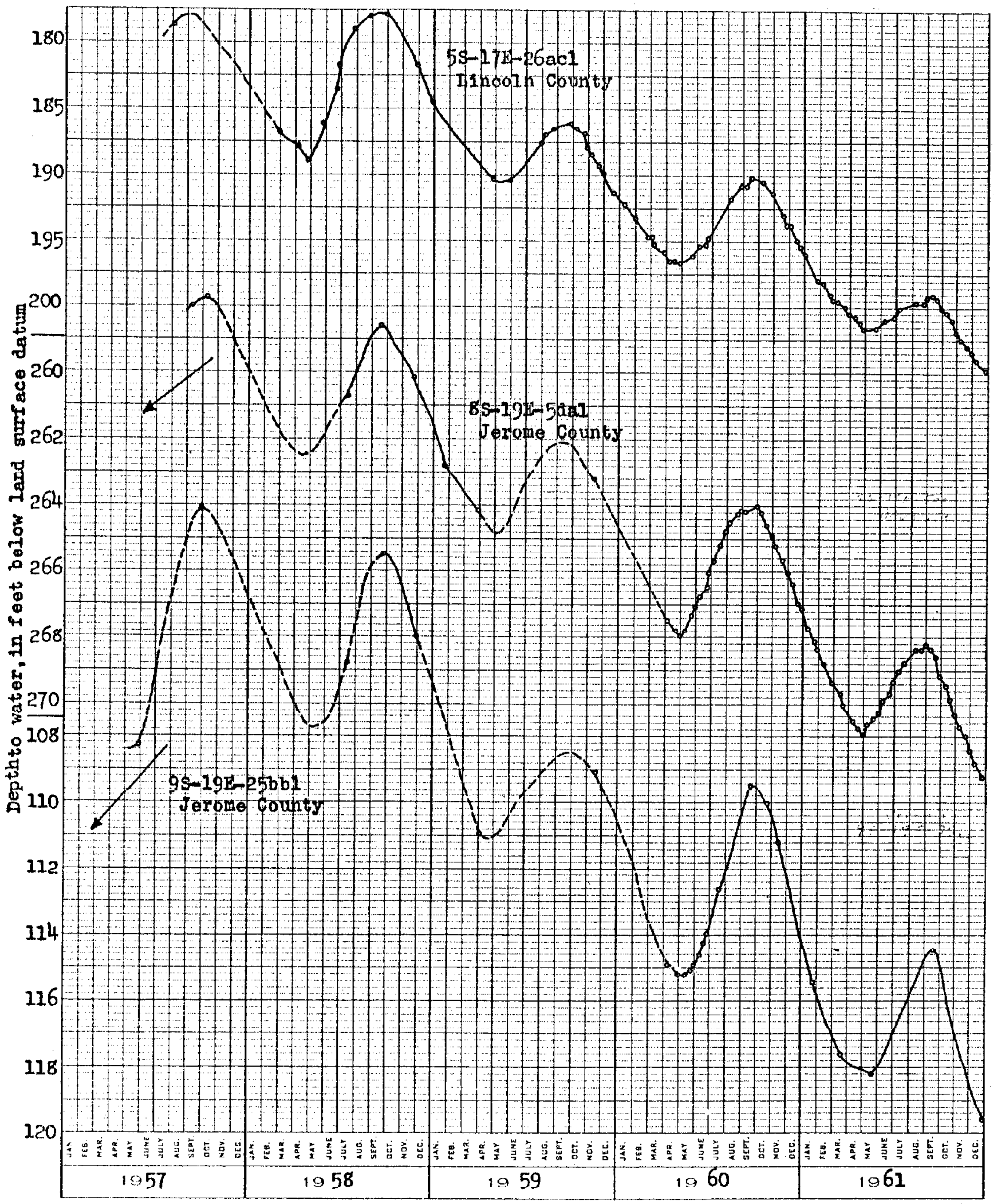



Figure 44.--Hydrographs of wells 5S-17E-26acl, 8S-19E-5dal, and 9S-19E-25bbl.

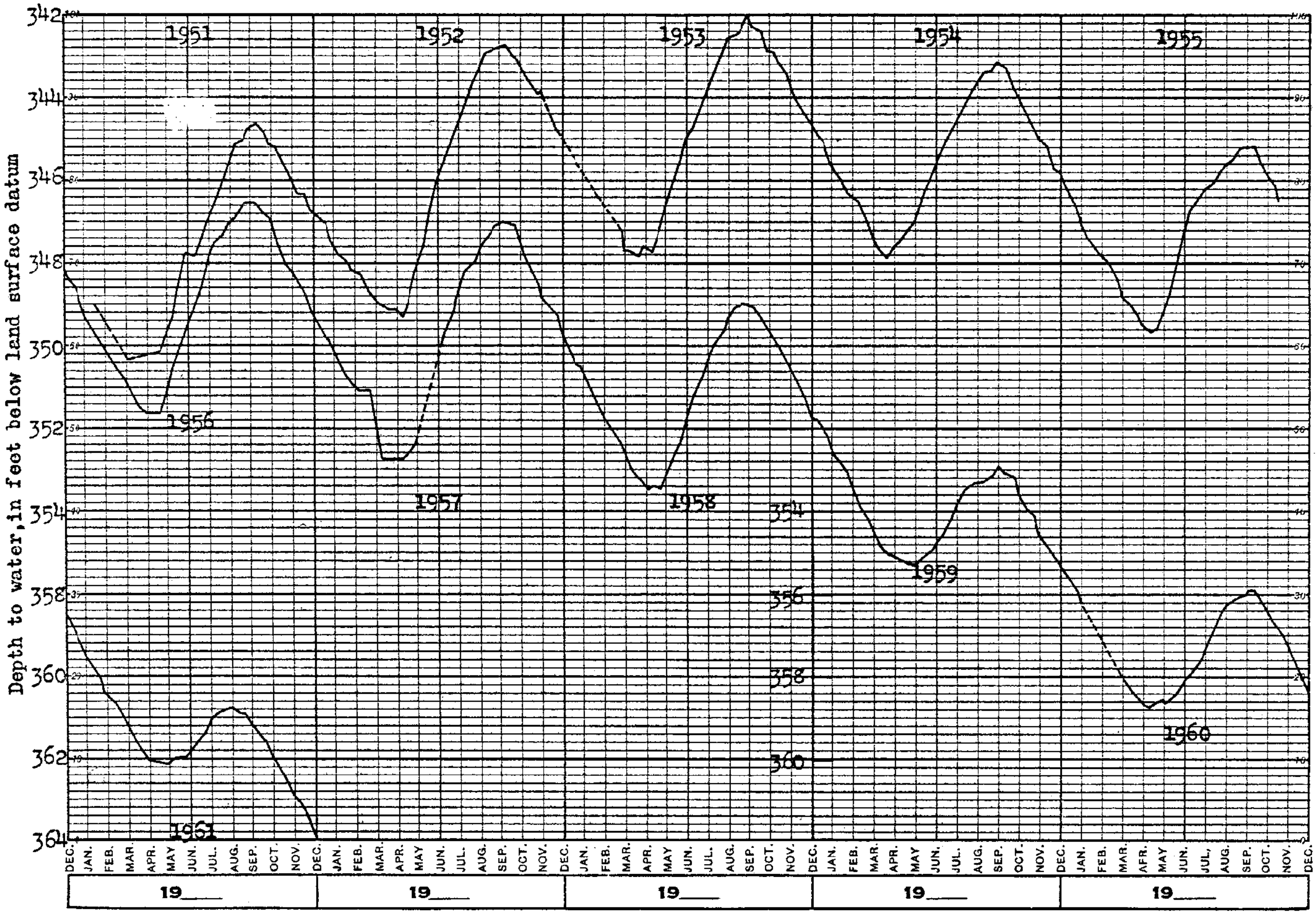



Figure 45.--Hydrograph of well 9S-20E-1dal.

the water table by recharge and therefore the values given in the cited report can be used. That is, the rise in the water table would be roughly 7 to 10 feet at the end of one recharge cycle, at a recharge rate of 250 c.f.s., and 10 to 13 feet at the end of 50 cycles. This would be the rise in the aquifer within the recharge area; the rise at distant points would be less.

The spread of a recharge mound from this area can be approximated by analogy with the spread of the cone of water-table decline caused by pumping in the Minidoka area. The water table began declining in 1954 immediately adjacent to the Minidoka Project area (hydrographs of wells 8S-24 E-31dcl, and 8S-23E-2bcl, figure 8). These wells are 55 miles east of the Hagerman Valley discharge reach. The water level in well 8S-14E-16bcl (fig. 46) which is about a mile from the discharge area did not show any decline until about 1958, and the decline was minor until 1960, but was greatly accelerated in 1960 and 1961. Thus it seems that it took 4 years for the increased pumping to affect the water table about 40 miles downgradient from the margin of the pumped area, and 6 years before the effect was appreciable. By analogy then, the spread of a recharge wave from a recharge area along the Milner-Gooding Canal some 30 miles away would require 3 to 4 years to affect the water table in the vicinity of well 8S-14E-16bcl.

## Wood River basin

In a previous section of the report it was shown that annual discharge from the Big Wood River drainage exceeded 9,900 acre-feet in 17 years, and averaged 185,000 acre-feet in the 23-year period 1938-60. Not all the water could be salvaged for recharge but perhaps an average of 100,000 acre-feet could be. Part of this water would be available from Little Wood River and Silver Creek.

Originally large amounts of water were lost from the channel of Big Wood River downstream from Magic Reservoir (fig. 3) to the Snake Plain aquifer (Smith, 1960, p. 27). Since 1925 the entire natural flow has been diverted through the Lincoln Canal (Smith, 1960, pl. 2) and losses are less. The abandoned river channel crosses and skirts a basalt flow of Recent Age (Shoshone Basalt flow) which is very permeable and takes water rapidly. According to the watermaster (Smith, 1960) average losses in a 15-mile reach of the channel were about 149 c.f.s. during the irrigation seasons 1920-25. The abandoned channel and adjacent areas of the basalt could be used for recharging large amounts of water. The Hailey and Twin Falls topographic sheets of United States series at a scale of 1:250,000 show that the altitude of the basalt flow ranges from about 4,600 feet at point 8 miles south of Magic Reservoir, to about 3,600 feet near Gooding. Water could be diverted from the river onto the lava flow at almost any point along its course. However, recharge in that part of the basalt northeast of Shoshone would be more effective in raising water levels over a wider area, and being farther from the Hagerman Valley discharge area, would maintain water levels for a longer time than would recharge farther to the west.

This recharge area is about 30 miles from the Hagerman Valley, and on the basis of rate of spread of effect of large scale withdrawal in the Minidoka-Hazelton area, it probably would take several years for the effects of recharge in the basalt northeast of Shoshone to reach the Hagerman Valley.

## Methods of increasing intake

It is apparent from the preceding general description and the discussion of the individual recharge areas, that one of the major problems in artificial recharge in the Snake River Plain, is to get the water through layers of low-permeability materials, down to the main water table. These materials of low permeability at some places cover the basalt surface, and at others they occur as interbeds.

The effect of these low-permeability layers is to increase the area required for water-spreading, perhaps tenfold, or more. This may not be a serious problem where large areas of public domain have little other use. However, the cost of dikes and other structures required to conduct the water from pond to pond might be substantial. Also, in some areas it may be desirable to keep the flooded areas smaller. Therefore, some method of increasing the volume of intake per unit surface area may be desirable. Several methods are described below.

### Removal of surficial materials

In some areas, particularly in the Plano-Roberts area, windblown sand and silt have accumulated in depressions in the basalt. The bottom of each depression is blanketed with these deposits, and water must percolate through them. At places basalt is exposed along the flanks of the depressions, but most of the cracks and crevices in the basalt are partially choked with sand and silt. Many of these, especially the gaping crevices in pressure ridges, are capable of taking large amounts of water where they are not plugged. Some individual crevices might take tens of cubic feet per second. It might be possible to increase the intake of water by removing the sand from individual crevices by hydraulicking. Water from the recharge ponds could be used as the ponds filled. Once a crevice was clean, graded gravel could be used to fill it to prevent it from again filling with sand.

It is possible that heavy blasting at favorable spots, perhaps in crevices of the pressure ridges, would open up new channels for the downward percolation of water.

### Galleries and injection wells

Where a layer of silt and sand a few feet thick overlies the basalt, wells drilled into the basalt could be used to increase the recharge rate. In order to prevent silt and debris from directly entering the basalt, the water could be filtered through gravel. A 20-inch to 24-inch casing

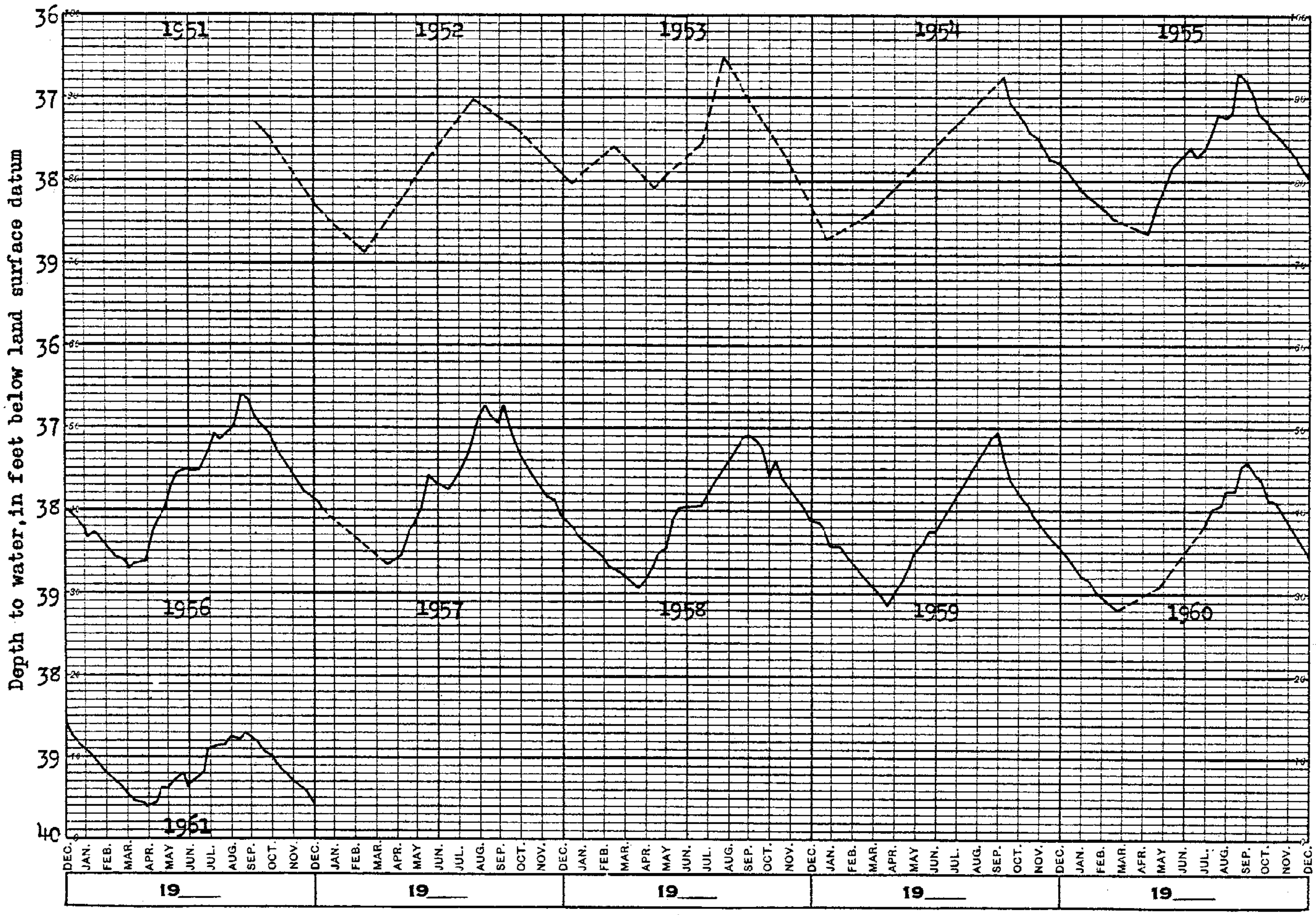



Figure 46.--Hydrograph of well 8S-14E-16bcl.

would be cemented into the top of the basalt, and the uncased hole continued on into the basalt. In one method the casing would be perforated, the sand removed from around the casing, and the annular space back-filled with gravel (fig. 47A). Alternatively, 8-inch perforated pipe or tile could be placed in a shallow trench leading into the well, and the trench back-filled with gravel (fig. 47B).

In most areas where surface water can be diverted onto basalt surface of the Snake River Plain, the basalt flows have one or more interbeds of fine-grained material at some depth, for example, the 34-foot silty-sand interbed beneath 36 feet of basalt in the vicinity of the TW-10 recharge test. These interbeds cause perched aquifers to develop. If the perched aquifers spread widely enough, all the water will seep downward to the main aquifer. However, in spreading widely they may reach farmed areas and cause waterlogging and seepage problems. Therefore, it may be desirable to increase the percolation rate. This could be done by drilling a well connecting the basalt above and below the interbed, so that water could flow from the perched aquifer into the well bore, down the bore, and out into the main aquifer. By connecting the two aquifers, instead of injecting the water directly into the well at the surface, the possibility of pollution and of silting up of the aquifer would be minimized. Construction could be similar to that shown in figure 48.

## Conclusions

For more than 60 years, beginning in the 1890's and ending in the 1950's, the water table in the Snake Plain aquifer rose. This rise was caused by irrigation. The magnitude of the rise is not completely known, because records of the position of the water table prior to irrigation are not available for all parts of the plain. However, the rise probably exceeded 100 feet at some places, and the average for the entire plain may have been 60 to 70 feet.

With the great expansion in use of ground water for irrigation, beginning after World War II, and becoming quantitatively significant in 1952-53, the trend has reversed, and the water table is declining nearly everywhere beneath the plain. By 1960, ground-water withdrawals in the eastern Snake River Plain and tributary valleys reached 2 million acre-feet, and consumptive use was roughly 1 million acre-feet. The decline in water level between 1953 and 1961 generally ranged from less than a foot to about 12 feet. Ground-water withdrawals undoubtedly will continue to increase and the water table will continue to decline.

Artificial recharge will not reverse that trend, not enough water is available for that. However, recharge of a million acre-feet will permit pumpage of 2 million acre-feet additional water (assuming 50 percent consumptive use) without any additional decline in the water table.

Large areas of public domain now having only limited use for grazing, are available for recharge by spreading in shallow ponds. Surplus water can be diverted to these areas from Henrys Fork, the Snake, and Wood Rivers. Surficial conditions generally are favorable, the basalt surface contains many closed depressions, and additional depressions can be constructed by building low levees.

Small-scale recharge tests have revealed some of the problems; silty and sandy overburden greatly reduces the intake capacity of the basalt at some places, and sedimentary interbeds will result in perched water tables at other places. Where recharging is attempted under these conditions, larger areas will be required for water spreading. However, there are several different methods that can be used to increase the intake per unit area.

Present recharge from irrigation on the plain is on the order of 3.5 million acre-feet a year; in general, this recharge is accomplished in the worst possible sites for recharging operations, where the overburden and sedimentary interbeds are thickest and most extensive, and where the water table is nearest the surface.

Thus, although there will be problems connected with artificial recharge, for example, perched water tables might cause waterlogging of some nearby farm lands, there is no question but that large quantities of water can be successfully added to the ground-water supply.

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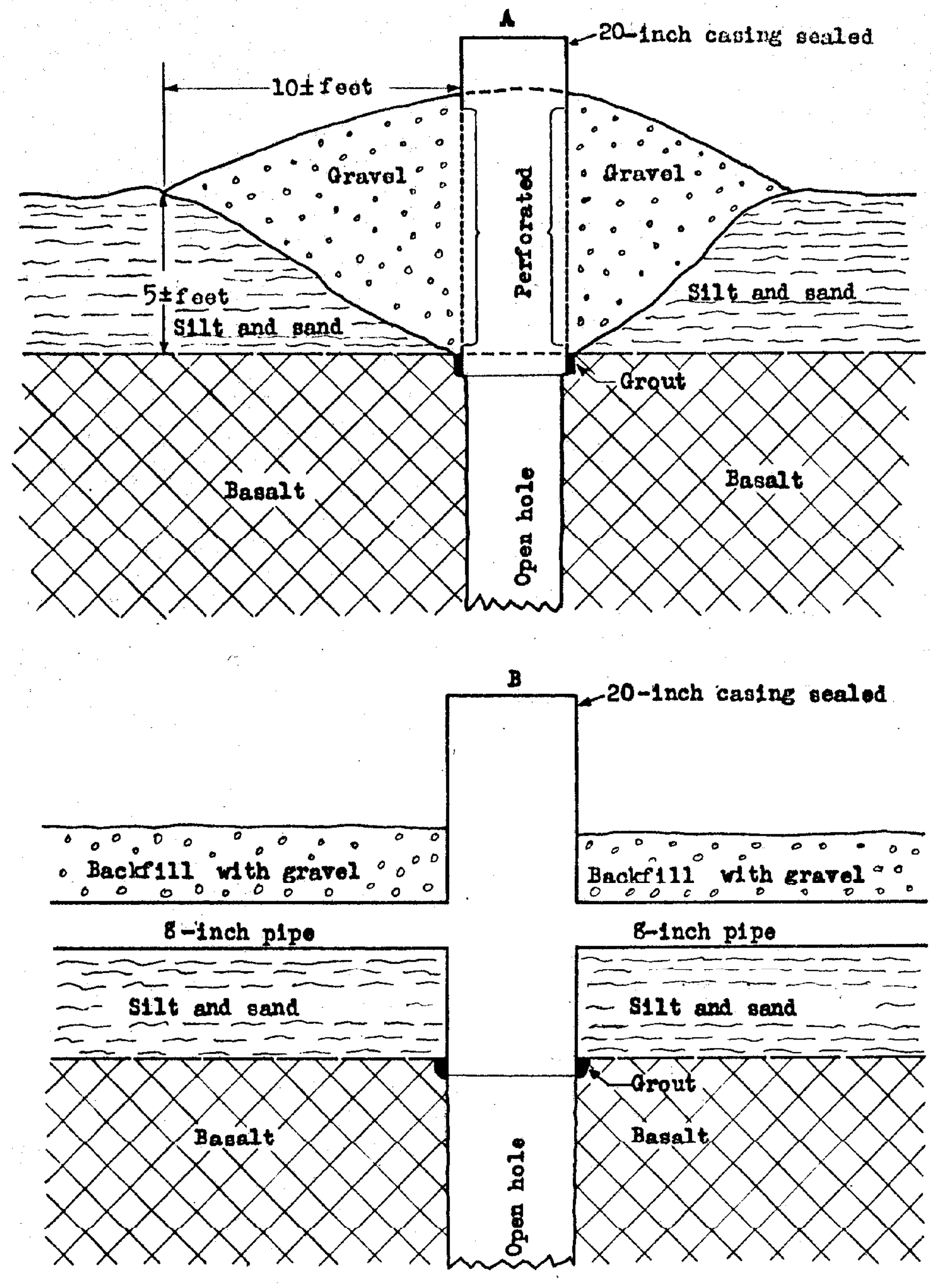


Figure 47A,B.--Methods of intake well construction to increase recharge to the basalt.

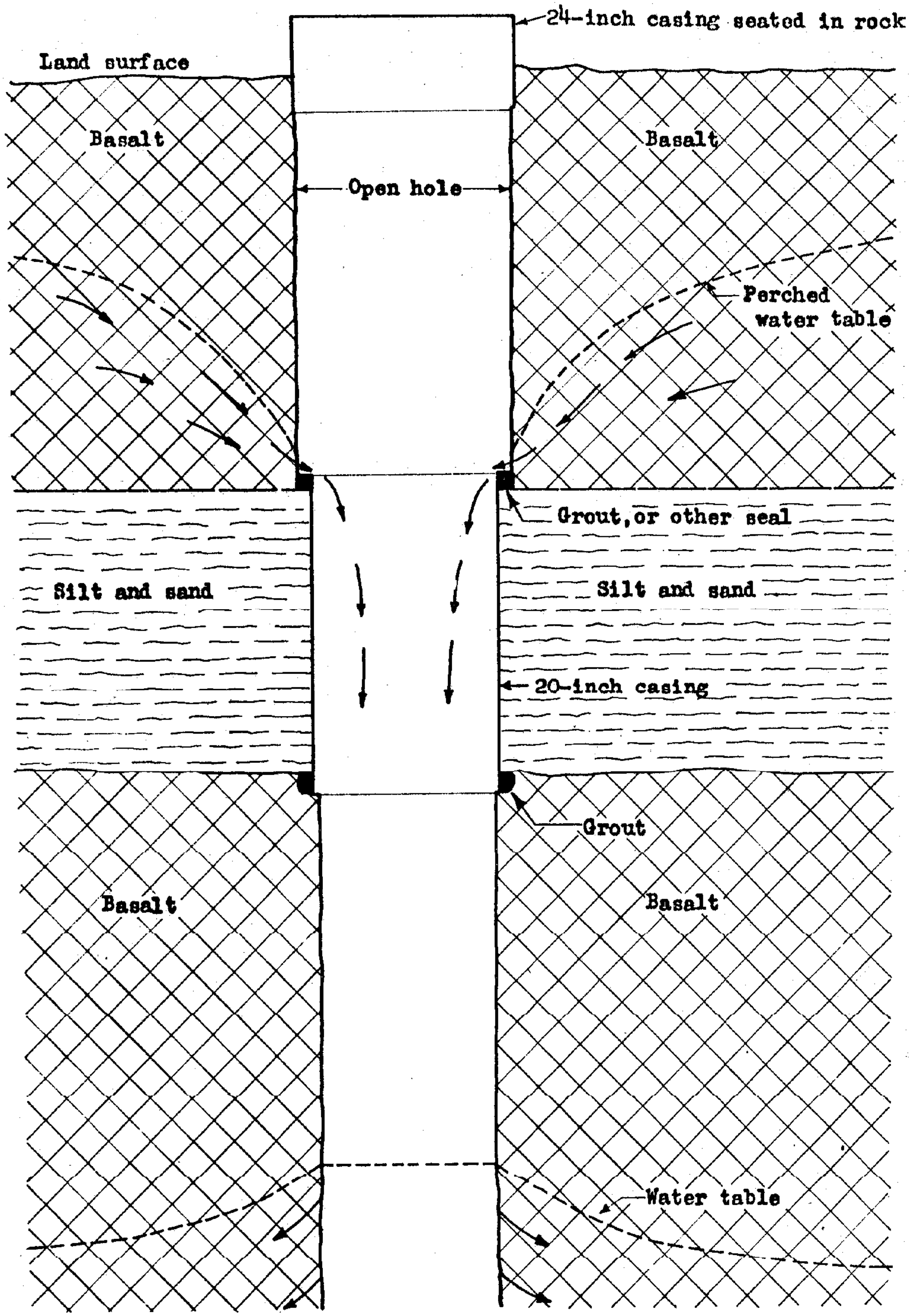


Figure 48.--Well construction to connect perched aquifer to main aquifer.

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